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# THESIS

**FLEXIBLE ARCHITECTURE SYSTEM & TOPOLOGY LICENSE PLATE RECOGNITION (FAST LPR) AND CONCEPT OF OPERATIONS IN THAILAND**

by

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September 2008

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13. ABSTRACT

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     Illicit drug trafficking is a phenomenon that cannot be addressed autonomously. Rather, evidence strongly relates illicit drug trafficking to terrorism activity, in a relation that is highly reciprocal. In the past decade this common front is described by the term "narcoterrorism," stressing the correlation of these two areas of illegal activity, which until recently were independent of one another. Clearly, the only response to the sophisticated narcoterrorism networks must be based on advanced technological tools. The Flexible Architecture System and Topology License Plate Recognition (FAST LPR) system is a promising solution to this problem.

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# I.    INTRODUCTION

## A.    PURPOSE

The purpose of this thesis is to examine the impact of illicit drug trafficking on the regional stability of Southeast Asia in general and Thailand in particular in combination with other present destabilizing factors like the insurgency in the southern provinces of the country as well as the border disputes with the People's Democratic Republic (PDR) of Lao, Cambodia and Myanmar. With technology playing an important role for drug traffickers and law enforcement authorities, it becomes necessary for legitimate governmental organizations responsible for monitoring illicit drug trafficking and coercive action to be equipped with cutting edge equipment to maximize their effectiveness. The Flexible Architecture System and Topology License Plate Recognition (FAST LPR) system is one of the systems funded by the U.S. DoD/Counter-Narcoterrorism Technology Program Office. FAST LPR is designed to assist law enforcement units in their border control mission as well as critical traffic nodes throughout Thailand. The low profile of FAST LPR, with its endemic mobile nature and the almost intuitive graphical user interface (GUI), can minimize the required background knowledge of a user without compromising the expected accuracy. Also, its various modes of operations render FAST LPR a really flexible system serving the counter-narcoterrorist units almost on the fly. Part of this thesis, beyond describing the system's components and architecture, is the experimentation that took place before the FAST LPR team came up with the system's final configuration as well as the Concept of Operations (CONOPS).

## B.    IMPORTANCE

The idea of having different illegal groups operationally connected to maximize their goals and keep their potential losses to the lowest possible level is not new. Besides, it reflects one of the basic principles of war, which is concentration of force. The nature of the reciprocal relationship between drug trafficking groups and terrorists had not been

given proper attention, despite the first signs that appeared in the 1980's.[1] It was in the wake of the terrible attacks on 9/11 that the term narcoterrorism started to become part of the vocabulary of law enforcement authorities as well as policy makers. The reciprocity of this relation is based on the necessity of both sides[2] to fulfill their often distinct needs. Illicit drug traffickers need to lower the risk[3] while trafficking drugs and thus protection is what they need. Terrorist groups, especially those lacking other funding sources,[4] need part of the profit of the drug trafficking activity to stay in the business; they need funds to acquire weapons, to pay their members, and to support their ideologies[5] in other domains. It looks like a win-win solution for the traffickers and the terrorists.

The nature of narcoterrorism is dynamic, in the sense that illegal groups stick together for as long as they need to work together. New "alliances" form when there is a need for it, and their life cycle is determined by how profitable the whole business becomes. In addition to the dynamic nature of these relationships, there is also flexibility. Without the burden of official agreements between drug lords and terrorists, procedures tend to be expedited. There is no need to sign contracts, no lengthy negotiations, no wasted time. Even between different neighboring countries, the physical border does not pose a significant difficulty. Profit for both is all that matters.

That is the exact opposite of how things work when a legitimate national or international joint force is needed to counteract drug trafficking. The legal framework usually leads to delays. Bureaucracy tends to create a gap between what the expected outcome really is and what finally becomes the field implementation. Different training

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[1] FARC and Hezbollah.

[2] Illicit drug traffickers and terrorist groups.

[3] Reduced risk often translates into less drug load seizures during the trafficking phase, hence more profit.

[4] Abductions on a regular basis, for example, or support from states like Iran, or even from diasporas throughout the globe. It is believed though that the profit from supporting drug trafficking is by far better, in terms of income, compared to all the other sources.

[5] Common ideologies are request for autonomy or even secession, religious based goals, and so on.

of the participants is often problematic. Different equipment, mentality, mindsets as well as interests keep the joint operation from being successful. Also, interagency rivalries[6] sometimes play an undermining role.

Also, with the advent of critical technological achievements like the Internet, GPS-based applications, cellular phone networks, satellite communications, wireless computer networking, and many more, the counter-narcoterrorist[7] arena has shifted to another level. It is not cost-effective for the terrorists, and sometimes not feasible at all, to display conventional power against legitimate national or international forces. They do not have the luxury of such manpower. Besides, that kind of confrontation was never the mindset of terrorist groups; the most favorite tactics were similar, if not identical, to the guerilla warfare-based tactics, and these tactics remained the same for centuries. It is the technology that now offers new ways of applying them on the field. The decentralization of guerilla operations, the effort to keep the situation as fluid as possible, the luxury of picking the time and place of strike, and many other ideas have been well documented by Mao Tse Tung.[8] Amazingly, in his book[9] David Galula ends up getting the same findings as Mao Tse Tung. It seems that insurgency warfare is way more standardized at the abstract level of general ideas than the conventional way of thinking when it comes to war.

The counter-narcoterrorism forces have at their disposal the same level–and often more–access to technology in the broader sense. It is just the hierarchy or the structure that sometimes does not allow them to take full advantage of the technology. Information sharing, real-time flow of data, intra-service source sharing, and single unity of command are great, but they need also to be implemented at the field level. The decision of restructuring the law enforcement units, police, military, intelligence, or other potential players is a high-level political decision and is beyond the scope of this thesis. Field

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[6] Between police and military forces, for example. Typical indication is the limited information sharing.

[7] As part of broader terrorism.

[8] Tse Tung, *On Guerilla Warfare*.

[9] Galula, *Counterinsurgency Warfare*.

applications though like FAST LPR, made up from commercial off-the-shelf (COTS) components, is a great example of the wise use of technology on the "good guys' side." Using technology to assist counter-narcoterrorism can be seen as a force multiplier. Smaller units become more effective and by being inherently more mobile and flexible they can react faster. They can be stationed in forwarded areas as well as rough terrain and change their geographical location, thus surprising the narcoterrorists. Most importantly, they maintain a low profile by doing their job the old-fashioned way and thus, not threatening the local population. The latter can be very important especially when counter-narcoterrorism operations take place in ethnically sensitive regions[10] of the country.

## C.    MAJOR ARGUMENTS

Illicit drug trafficking, as part of the broader narcoterrorism issue, is a major threat for the stability of sovereign countries. When there are regions within a sovereign state where the legitimate government has little or no control, then stability is undoubtedly at stake. Especially when, along with the shallow governmental reach there are other underlying destabilizing factors such as religious turmoil, disparate wealth distribution, ethnic grievances and population oppression, the situation might go out of control for the legitimate government. The caused instability and potential turmoil acts in favor of narcoterrorism, by allowing the illicit drugs to flow easier along their routes. The law enforcement has to deal with multiple threats, not just the traffickers. Thus, dispersed as they become, legitimate forces are less effective against illicit drug trafficking. That way the profit made by the drug lords gets bigger. Part of the drug profit then is directed to keep the turmoil active, in order for the drug traffickers to continue to operate unimpeded. The maintenance of instability and turmoil is a by product of the illicit drug trafficking, and a facilitating factor at the same time. Hence, a government's response should target both these elements.

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[10] Like the Muslim-dominated southern provinces.

This thesis deals with the potential contribution of FAST LPR in increasing the capabilities of law enforcement in Thailand as far as the illicit drug trafficking along land routes is concerned. The more effective the counter-narcoterrorism becomes, the higher the risk of moving drugs through a certain road network. This increased risk, in turn, leads to increased prices for the drugs being trafficked through the region. Since drug business is a very competitive arena, if prices exceed a certain level, then the product stops being profitable. It follows that drug lords can accept only a certain amount of increased risk that translates into a subsequent drug price increase. After that point, the profit does not worth the risk. In such cases, the high risk trafficking routes have to be reevaluated, and the traffickers most likely will have to change the routes being used, in the pursuit of the path of least risk.

In Thailand, the road network is by far better and bigger than in any of the neighboring countries. This is very tempting for the illicit drug traffickers, because it can lead to reduced trafficking cost. Also, using conventional vehicles that are merged with the general traffic helps further reduce the risk of drug load seizures. Taking advantage of the quality road network the drug loads can be moved faster from point to point, be it major cities like Bangkok, small ports for illegal export or other transportation hubs.

The argument is that the easiest and most obvious way to better control and disrupt the flow of illicit drugs through Thailand's roads is by monitoring the traffic arteries throughout the country. This is a tough task to do, given the area of Thailand and the density of its road network. Any system that could help counter-narcoterrorism forces multiply their effectiveness would significantly strengthen the overall attempt to "make Thailand a drug-free country, by 2015."[11] FAST LPR is a system that is developed to address the problem of monitoring road networks based on vehicle's license plate recognition and subsequent comparison versus license plates stored in one or more databases. The system can operate day and night, with it's sensors scanning a certain volume of traffic (interstate lane, junction, curved turn, toll post). Any Thai license plate that crosses the sensors' field of view (FOV) triggers the system. The license plate

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[11] ASEAN goal, initially scheduled for 2002, and later shifted to 2015.

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content is captured by the computer and recognized as set of characters (Thai characters and/or numbers). Then, the license plate is compared to the available database. If there is a match between the license plate and a record on the database, the system alerts the operator with various cues. The exact action to follow has to do with the law enforcement concept of operation for the specific setting. The contribution of FAST LPR is completed when the appropriate cues are issued. Further actions are outside the scope of the system as well as this thesis.

FAST LPR is a system that consists of COTS building hardware blocks. The main components are sensors/cameras, infrared (IR) illuminators, capture computer that are commercially available. This follows the general trend of integrating non-specially designed components into systems, often for military use, in an attempt to reduce the research and development cost. Also, COTS components lead to more open hardware architectures, hence easier for the end user to interchange certain elements with newer ones. On the other side of the coin, COTS components are often proprietary and their detailed specifications might not be releasable. This is a challenge for the system developing and integration, especially when specific standards or specifications need to be met. In the FAST LPR developing there were many components that were supposed to be ideal, based on their individual stated performance, but when integrated in the system they became the weak link degrading the overall performance. Finally, after many months of analysis as well as field experimentation, FAST LPR met the specified goals as these were set by the funding organization, U.S. DOD/CNTPO.

## D.    BORDER CHALLENGES

Thailand is geographically surrounded by Myanmar, Lao PDR, Cambodia, and Malaysia. Myanmar is the second biggest opium producer globally,[12] and the production of other drug substances is also significant. In Lao PDR, opium production appears to be declining,[13] yet drug trafficking[14] is still an issue. In addition, there are border disputes[15]

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[12] U.N. Office on Drugs and Crime, 2008 World Drug Report, 2008 (New York).

[13] Ibid.

[14] "The World Factbook: Thailand," Central Intelligence Agency, http://www.cia.gov/library/publications/the-world-factbook/print/th.html (accessed April 21, 2008).

between Thailand and Lao PDR, especially in the northern part near the Mekong River. The borders with Cambodia are another area of contention, and recently tension between Cambodia and Thailand peaked as a result of the old issue of the Preah Vihear Temple. Both militaries escalated[16] their presence near the borderline. Finally, Thailand's southern provinces are considered the country's "soft underbelly," since the separatist[17] movement there is constantly engaged in a low-scale insurgency that often manifests itself with bomb attacks that take place in the periphery as well as in Bangkok or other major cities. It is obvious that the Thai military is facing challenges of a different nature[18] all across the country's borderline.

A growing amount of evidence suggests that Thailand's organized crime, illicit traffickers, and insurgencies are all somewhat linked. Trafficking includes, but is not limited to, illicit drugs, humans, and weapons. Recently, the government of Thailand has stated that it plans to wage a new "war on drugs."

The major drug-producing group in the area is the United Wa State Army (UWSA).[19] UWSA is the successor of the Wa organization that was the primary fighting force of the Burmese Communist Party (BCP). The force of UWSA is believed to be approximately 20,000 well-equipped people.[20] They are equally involved in drug trafficking, especially near the Thai border. The UWSA coveted areas close to the Thai border, to use them as "gateways to the strategic trade routes into Thailand."[21] Other paramilitary organizations near the Thai borders are Mong Tai Army (MTA), Eastern Shan State Army (ESSA) and Myanmar National Democratic Alliance Army (MNDAA).

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[15] "The World Factbook: Thailand," Central Intelligence Agency, http://www.cia.gov/library/publications/the-world-factbook/print/th.html (accessed April 21, 2008).

[16] Associated Press, "Troop Build-up Escalates at Temple on Cambodia-Thailand Border," *International Herald Tribune*, July 17, 2008, http://www.iht.com/articles/2008/07/17/asia/temple.php (accessed August 20, 2008).

[17] Crisis Group Asia Report No. 98, *Southern Thailand: Insurgency, not Jihad* (Singapore/Brussels: ICG, 2005), ii.

[18] Drug trafficking, separatist insurgency, narcoterrorism.

[19] "World Paramilitaries," Wa, http://www.globalsecurity.org/military/world/para.wa.htm (accessed September 2, 2008).

[20] Ibid.

[21] Ibid.

These armies, with the UWSA and MNDAA being the most extreme cases, are heavily armed. Their leaders are of known identity, but they remain untouched by the local authorities.

The United Nations Office on Drugs and Crime (UNODC) 2007 Report depicts three trends in the drug trade. Historically, opium is grown along Myanmar's eastern borders with China, Laos, and Thailand. Currently, opium is mostly concentrated in the South and East Shan States, which account for some 90% of all opium grown in the country. A recent reduction in opium cultivation has been offset by more lucrative methamphetamine production. As a result, the distribution of drug incomes has shifted away from poor farmers (producing opium) to criminal groups (producing synthetic drugs).

In recent years, routes through southern Thailand have been on the agenda of both traffickers and anti-drug forces, particularly since March 2000, when several million methamphetamine pills were seized in Prachuap Khiri Khan, having been trafficked from Kawthaung, or Victoria Point, in Myanmar to Ranong, Thailand. In January 2001, another seizure confirmed this reorientation of drug trafficking through southern Myanmar and Thailand. Close to eight million pills and 116 kg of heroin were seized aboard Thai fishing boats west of the Ko Surin Islands, indicating that the Andaman Sea is a major drug route. Eighty percent of the drugs entering Thailand come across the northern part of the Thai-Myanmar border, but the strengthening of Thai anti-drug actions has clearly fostered a wide diversification of drug trafficking routes as well as a diminution of the quantity of drugs being transported at any one time.

The UNODC put Thailand among the countries most favored by those involved in 21$^{st}$ century slavery. According to a 2006 press release, Southeast Asia and South Asia are home to the largest numbers of internationally trafficked persons, at an estimated 225,000 and 150,000 respectively. Thailand, in addition to being a destination country, serves as a source and transit hub for other Asian countries such as Myanmar, Cambodia, and Lao PDR. Many of those being smuggled into Thailand are used for their labor in brothels and textile mills.

Thailand is considered an international hub of arms trafficking in small firearms, machine guns, ammunition, and lethal weapons such as surface-to-air-missile launchers and explosives, despite efforts by the government to make Thailand "free of firearms." For decades, Thai authorities turned a blind eye to smuggling as these weapons were not used against the Thai people. In some cases, the Thai military and police personnel in official control of weapons and ammunitions have been caught selling them from national stockpiles.

The vast majority of illicit drug influx into Thailand is being trafficked using Thailand's exceptionally good road network. The official border crossing points are mainly used however there are other points from which illicit drug loads penetrate the borderline. The overall length of the Thai land borders is 4,800 km (2,983 miles) and sealing the borders is just not feasible. In addition, to circumvent the land border stations, often drug traffickers use other means of transportation, like small boats. Once the illicit drugs are in Thailand, then the normal land road trafficking is resumed.

The law enforcement scheme responsible for guarding the borders is the Royal Thai Border Police, augmented by the Royal Thai Border Police Aviation (RTBPA). Its roles and responsibilities include anti-smuggling operations and border patrolling. Often it is also involved in medical evacuation, anti-rebel, anti-piracy and other similar tasks. The main airbase the fixed wing and rotary wing air assets are operating from is Don Muang, in Bangkok. RTBPA is also manned and equipped for doing paratrooper operations (Figure 1), which in some cases is the quickest possible way to send troops on the ground in mountainous areas close to the northern borderline.

Figure 1.     RTBP Paratroopers[22]

Based on the information presented above, there is no doubt that Thailand is facing an important threat, or put another way, "According to Thai military officials, the foremost threat to Thailand's national security–greater than any since the communist insurgency of the 1970s and early 1980s–lies along the northern border."[23]

The emerging trend of terrorism, that of loosely related[24] war lords, drug traffickers, and terrorist groups under the concept of narcoterrorism is indeed something new in the region. It is a branch of a broader category, that of so-called dissident terrorism.[25]

> Drug traffickers have especially been prone to engage in criminal dissident terrorism- so-called Narcoterrorism- because their product must be grown, refined, packaged, and transported from the production regions within the borders of sovereign nations. Thus, among international criminals, drug

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[22] "Thailand: Nation, Religion, King," Sea Air Thai Co. Ltd., http://www.nationreligionking.com/police/borderpatrol/paru/airbornetraining/?image=in00601 (accessed August 18, 2008).

[23] "Thailand's War on Drugs," http://www.globalsecurity.org/military/world/war/thai-drug-war.htm (accessed June 16, 2008).

[24] Organizationally as well as temporally.

[25] Gus Martin, *Understanding Terrorism: Challenges, Perspectives, and Issues* (Thousand Oaks, CA: Sage Publications, Inc., 2003), 112.

traffickers in particular must necessarily establish a political environment that is conducive to their illegal enterprise. The goal of criminal dissidents is to protect their illegal enterprise.[26]

The vital interest that the drug traffickers need to protect is their product. Once that is achieved, the next objective is to maximize their profit. The smaller the number of seized loads, the larger the profit becomes. The protection that they need is delegated by subcontracting the specialists in the region, i.e., local terrorist groups. If they can guarantee the uneventful delivery of the product to the final or intermediate destination, they get paid, and the traffickers make more profit. In general, it is a win-win situation. The money paid to the terrorist groups is generally used to maintain their ability to support their ideology, which is most often of a political nature.

## 1.    Counter-narcoterrorism Application of FAST LPR

The profit-oriented nature of the narcoterrorists is their Achilles' heel, in the sense that the best way for the local counter-narcoterrorist forces to deal with the illicit drug trafficking is not to try to vanquish them,[27] but simply to discourage them from using the specific region for their illicit activities. The less profitable a specific trafficking route becomes, chances are the traffickers will seek for another, cheaper route. While globally this is not a promising solution, it works on a local basis. The best metaphor is to think of the illicit drug trafficking as a perforated bucket full of water. Water spills out of hundreds of tiny holes in the bucket. With just two bare hands,[28] no one is able to stop the leak. As the two hands are blocking a decent amount of the bucket's surface and they stop the leak from the specific region[29] of the bucket, the water finds another way to get out of the bucket using the unblocked holes and the outflow of the remaining number of

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[26] Gus Martin, *Understanding Terrorism: Challenges, Perspectives, and Issues* (Thousand Oaks, CA: Sage Publications, Inc., 2003), 112.

[27] Most often this is just not possible, requires a tremendous amount of funding as well as manpower, or might have secondary effects on the local population.

[28] Representing the limited manpower and/or funds dedicated to the counter-narcoterrorism effort.

[29] Country, province, etc.

holes is characterized by increased–compared to the unimpeded flow–flow. Locally, though, the outflow is controlled. Nature is always in the pursuit of the path of least effort.

FAST LPR in the metaphor used is the blocking element. It can very effectively help address the illicit drug trafficking problem, but most likely the drug lords and the drug traffickers will soon find alternate routes through other countries less effective in intercepting the drug loads. Nevertheless, the contribution of FAST LPR is vital in increasing the risk involved in drug trafficking as far as the narcoterrorists are concerned, making them reroute their product through other regions and thus help local counter-narcoterrorist forces achieve their goal.

The various ways for responding to terrorism in general can be categorized as counterterrorism and antiterrorism. The former is about proactive policies. The primary focus is on eliminating these terrorists groups as well as their environment. The latter, seeks to "deter or prevent terrorist attacks."[30] FAST LPR belongs to the counterterrorism quiver, and since its primary focus is on the illicit drug trafficking portion, it is a counter-narcoterrorism system. That "counter" nature of the system is what the sponsoring authority CNTPO[31] is looking for in the future of counter-narcoterrorism. The goals CNTPO wishes to achieve by activating FAST LPR in the field are of a proactive nature.

In further breaking down the available counter-narcoterrorism options, FAST LPR serves the purposes of the "repressive options," which are defined[32] as "military operations other than war[33] and nonmilitary operations other than war."[34] Though not its primary purpose, FAST LPR can be used to gather intelligence and thus populate–and

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[30] Gus Martin, *Understanding Terrorism: Challenges, Perspectives, and Issues* (Thousand Oaks, CA: Sage Publications, Inc., 2003), 345.

[31] For a detailed description of the mission of the U.S. DoD/CNTPO visit: http://www.cntpo.com (accessed June 20, 2008).

[32] Gus Martin, *Understanding Terrorism: Challenges, Perspectives, and Issues* (Thousand Oaks, CA: Sage Publications, Inc., 2003), 346.

[33] MOOTW.

[34] NMOOTW.

keep on populating–the required "lists."[35] The category that FAST LPR fits under, based on Martin's definition, is "enhanced security." That is, the purpose of such systems is to "harden the targets and deter or prevent terrorist attacks. Security barriers, checkpoints and surveillance are typical security measures."[36]

Last, for reasons that will become apparent in the following chapters, hard-line responses are not the approach of choice for countries like Thailand, where there was a significant and fruitful counter-narcoterrorism effort the last decade, in light of the other low-level issues that the country faces. Suffice to say, that hard-line approach would be ideal for domestic counter-narcoterrorism operations where domestic threats would be adequate to justify the use of military or police in a coercive manner. The fact that in Thailand there is no such reason to justify coercion, along with the unacceptable collateral damage that coercion brings into play, renders the hard-line approach inappropriate, if not dangerous,[37] for Thailand.

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[35] Databases; white list contains license plates that are safe, black list contains the previously registered license plates as threats, and the yellow list contains the license plates that need further declaration, namely suspect.

[36] Gus Martin, *Understanding Terrorism: Challenges, Perspectives, and Issues* (Thousand Oaks, CA: Sage Publications, Inc., 2003), 347.

[37] The last thing Thailand would ask for would be a resurgence of the different low-scale crises that exist.

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## II.    BACKGROUND

### A.    HISTORICAL BACKGROUND

Shortly after the end of WWII, a civilian government was ruling Thailand. An election was held in 1946, but the political arena was flurried. Eventually, in 1947 another coup ousted the government. A new set of restoration steps were taken, mainly regarding education. The clear anti-communist orientation of the new government was very conveniently located in time and place, especially for the U.S. forces. "Thailand provided ground, naval, and air units to the United Nation forces fighting during the Korean War."[38] In 1955, a long bilateral cooperation between Thailand and the U.S. started, marked by important agreements around the use of Thai military bases by U.S. forces. This cooperation still holds and is broadened beyond strict military-oriented activities. Nevertheless, the importance of the Thai-U.S. agreements became obvious in 1965, with the U.S. involvement in the Vietnam War.

In 1969, a new government emerged. There were new issues for the government to deal with; "the Muslim insurgency in southern Thailand, communist guerillas operating in jungle areas north of Thai-Malaysian border, the successes of communist forces in Vietnam and Laos, and other regional unrest and protest against the government."[39]

The following period was a transition to democratic rule (1973-1976), military rule and limited parliamentary government (1976-1992), and multi-party democracy (1992-2006.) The head of the Thai government during recent years is Thaksin Shinawatra.

Violence has plagued Thailand's Muslim-dominated southern provinces (Figure 2) since the beginning of 2004, with armed insurgents attacking police stations, security stations, and military depots. Nearly 800 people have been killed in the attacks, which officials attribute to Islamic militants. The violence intensified in July 2005, prompting

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[38] Country Profile: Thailand, Library of Congress-Federal Research Division, July 2007.

[39] Ibid.

Thaksin to declare a state of emergency in the south. The Pattani province was rocked by attacks in February 2007, when some 30 coordinated bombs exploded at bars, hotels, and electricity transmitters. While the insurgents have been vague in explaining their motivation for such attacks, the most recent bombings suggest they are targeting Buddhists as well as other Muslims. "More than 250 people have been killed in violence in the majority Muslim provinces of Pattani, Yala and Narathiwat."[40] Both indigenous and transnational forms of terrorism are evident in Thailand's southern provinces. The presence of this kind of violence, with the police and armed forces retaliating after any incident, are growing concerns about the transformation of Thailand's south as just another front "on the U.S.-led war on terrorism in Southeast Asia."[41] Besides, the U.S. and the Thai government have a close relationship in anti-terrorism cooperation, manifested by the Counter Terrorism Intelligence Center (CTIC) that was established in 2001. Among the goals of CTIC is to facilitate better and more efficient cooperation between the two countries in security-related issues, like the turmoil in the southernmost regions of Thailand. Thailand has been designated by President Bush "as a major non-NATO ally in recognition of its support of the war against terrorism."[42] The approach of characterizing the turmoil in southern Thailand as Muslim-based terrorism is debatable. Many analysts argue that the reasons behind the unrest should be in areas like illiteracy, poverty, illicit drug trafficking, and smuggling but not religion. Either way, the unsettled violence in these provinces best facilitates the drug traffickers in the sense that governmental forces are committed to controlling the unrest, and the exit paths leading from Thailand to Malaysia remain open. Also, the radical police response to various incidents alienates the Muslim population and makes them less willing to assist the official forces in their terrorist hunt. Unintended or not, supported or just exploited, the unrest in Thailand's southern provinces offers the narcoterrorists an ideal environment.

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[40] The Library of Congress, Congressional Research Service, Terrorism in Southeast Asia, 2004 (Washington, D.C.: 2004), 21.

[41] Ibid., 22.

[42] Ibid.

In the rest of the country's borders, the situation is somewhat different. The past successes of communist forces in Vietnam and Laos are not anymore[43] a credible threat for Thailand's National Security. Rather, the inheritance these regimes left to today's Laos and Cambodia is of some concern, asking for new borderline delineation especially along Mekong River. There are border disputes between Thailand and both Laos and Cambodia. From time to time, these disputes become acute and the military from all sides mobilize a significant number of troops along the borderline. Occasionally there are border closings, when the situation becomes ebullient.

The case of Thai-Myanmar relations is even more serious. There are issues related to ethnic rebels, refugees, drug trafficking and arms smuggling. In 2001 and 2002, Thai forces confronted Myanmar forces in a clash within Thai territory. The existence of close to 100,000 refugees from Myanmar who live in camps in Thailand near the border further inflates the already tensed situation. These refugees more often than not become the targets for rebel forces operating in Myanmar. This in turn makes the Thai border forces to counter-respond.

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[43] Compared to the Cold War era.
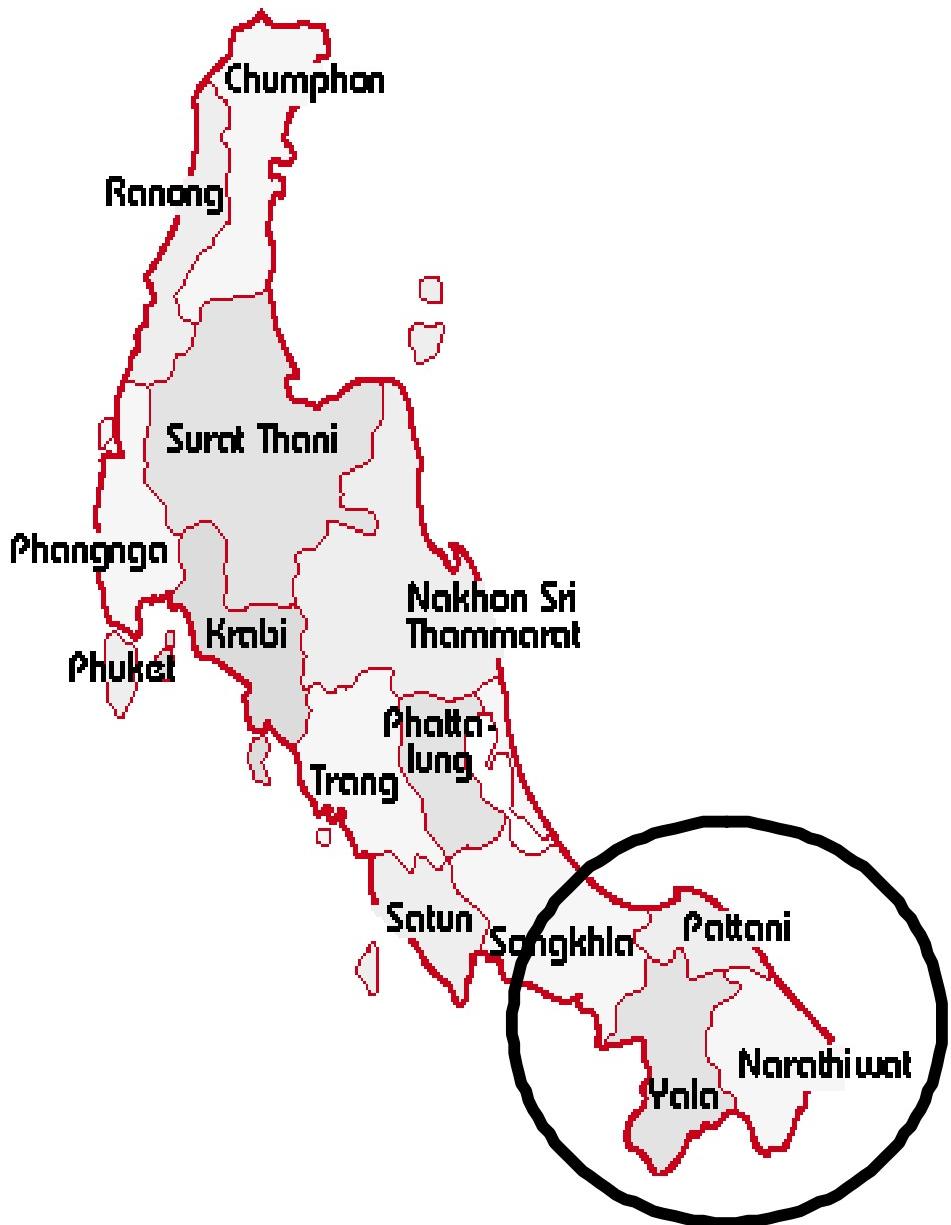
Figure 2.    Southern Thailand[44]

## B.    ILLICIT DRUGS PREVALENCE – THE GOLDEN TRIANGLE

The Golden Triangle is closing a dramatic period of opium production. Thailand has been opium-free for a long time. Vietnam is also opium-free. Laos has cut opium production by 94% in less than a decade. Myanmar's share of the world opium market has collapsed from 30% in 1998 to under

44 Global Security.org, http://www.globalsecurity.org/military/world/war/images/thailand-map3.gif, (accessed June 16, 2008).

6% in 2007. A decade's long process of drug control is clearly paying off. Thailand, in particular, stands out as an inspiration to its neighbours and a role model for other countries trying to overcome their drug problems.[45]

These were the first lines in the UNODC Annual Report for year 2007. The message was clear: there was a tremendous effort in this problematic region of the world, and for the first time in 2007, the situation in the front against opiates was roseate. Like any transition, to declare the region as drug-free is far from reality. Indeed, the same report stresses the importance of a continuous effort in order for the results to be sustainable. The symptoms were cut out, but the root causes are still there.

> Yet it is too early to declare the drug problem in Southeast Asia is over. In 2007, opium cultivation in Myanmar rose by 20% while production was up 46% thanks to higher yields… But they flash a warning sign that reminds us that Myanmar is still, by far, the world's second largest opium producer (at 460 tonnes). Myanmar needs a more effective counter narcotics strategy and more assistance, if it is to reach its target of being opium-free by 2014…The signs from Southeast Asia have been encouraging over a number of years. But there is no guarantee that progress can be sustained over time…The Golden Triangle should not be forgotten now that it is no longer notorious.[46]

As seen on the following bar chart in Figure 3, the decline in opium cultivation in the region since 1990 is remarkable. There are reversal trends, but in general, there is a steady downward impetus

UNODC's 2008 World Drug Report confirms the fear that the war against the opiates in Southeast Asia is "far from over," as described below in the previous year's report:

> On the supply side the story is different. This Report[47] provides evidence of a surge in the supply of illicit drugs in 2007. Afghanistan had a record opium harvest, and world opium production (because of higher yields) doubled between 2005 and 2007…The past few World Drug Reports have stated that the world drug problem is being contained in the sense that it had stabilized. This year's Report shows that containment is under threat.

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[45] *Opium Poppy Cultivation in South East Asia: Lao PDR, Myanmar, Thailand* (New York: United Nations Publications, 2007).

[46] UNODC Annual Report for year 2007.

[47] *2008 World Drug Report* (New York: United Nations Publications, 2008).

Urgent steps must be taken to prevent the unraveling of progress that has been made in the past few decades of drug control…Furthermore, containment should not be seen as an end to itself. Real success will only come when supply and demand actually go down.[48]

## 1.    Thailand

Based on CIA data, Thailand is considered only a minor producer of opium, heroin, and marijuana. It is also a transit point for illicit drugs that are enroute to the international drug market, mainly the U.S. and the European Union (EU). The countries, from which these drugs flow into Thailand, are Burma and Laos.[49]

Thailand remains a vital trafficking route for narcotics from the Golden Triangle–the intersection of Burma, Laos, and Thailand–to both the domestic Thai and international markets. The large-scale production and shipment of opium and heroin shipments from Burma of previous years have largely been replaced by widespread smuggling of methamphetamine tablets, although heroin seizures along the border continue to take place with some frequency. The United States and Thailand work closely together and with the United Nations on a broad range of programs to halt illicit drug trafficking and use as well as other criminal activity. In that context, FAST LPR is best suited to operate in Thailand along its road network. The system's performance can significantly help addressing the land-based illicit drug trafficking through the country. In addition, the U.S. supports the International Law Enforcement Academy (ILEA) in Bangkok, which provides counter-narcotics and anti-crime capacity-building programs to law enforcement and judicial officials from a number of regional countries.[50]

Nevertheless, Thailand's opium poppy cultivation increased between 2006 and 2007 by 46.8%, something that agrees with the region's trend. The bar chart in Figure 4 visualizes the course of the opium poppy cultivation area in the country since 1990. For the years 2003, 2004, and 2005 there is no credible dataset. Again, an increase from 2006

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[48] UNODC's 2008 World Drug Report.

[49] "The World Factbook: Thailand," CIA, https://www.cia.gov/library/publications/the-world-factbook/print/th.html (accessed August 16, 2008).

[50] "U.S.-Thai Relations," U.S. Department of State Background Note, http://www.infoplease.com/country/profiles/thailand.html (accessed August 16, 2008).

to 2007 is a worrisome sign. Also, the reported increase in synthetic drugs (ATS, mainly) trafficking is another concern. More sophisticated than the opiates, the traditional methods[51] the counter drug forces use do not yield important results when ATS are involved. Special methods and equipment is needed to assist in seizing that load of drugs, and even still, there will not be feasible to spread these hi tech labs throughout the country. FAST LPR can be the first line of defense in that direction too, since the system is not specific drug type based, but everything has to do with the license plate of the vehicle used in the trafficking business.

## 2.    Lao PDR

In Laos, the opium poppy cultivation has significantly declined over the last three years. The same holds true for the estimated potential opium production, with a constant decrease since 2003. The CIA reports that there is an emerging threat of methamphetamines, as both the local production and the consumption appear to increase. Year 2007 is "the third straight year of negligible levels of poppy cultivation in Lao PDR, with a further 40% reduction of cultivated opium poppy."[52] The same report, however, makes the following worrisome correlation between the successful eradication and the increase in opium prices in the area:

> With the average retail price of opium having increased to nearly US$ 1,000 per kilogram resuming cultivation of opium poppy must appear to be a very tempting source of income for poppy farmers. The current reduction in cultivation is dependant on the exercise and creation of appropriate and sustainable livelihood opportunities…Continued assistance and support from the international community remains crucial to ensure that the success achieved are not reversed.[53]

The opium poppy cultivation in Lao PDR, in hectares, is presented in the bar chart in Figure 5.

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[51] Use of sniffing dogs.

[52] *Opium Poppy Cultivation in South East Asia: Lao PDR, Myanmar, Thailand* (New York: United Nations Publications, 2007), 25.

[53] Ibid.

In Lao PDR, there was a reverse in the downward trend between 2005 and 2006 and again a decline between 2006 and 2007. As mentioned, this is no guarantee that in the future there will be further declines.

The applicability of FAST LPR or any other measure to intercept loads of illicit drugs is not applicable without the consent of the host nation. Therefore, it seems that little, if anything, can be done as long as the drug loads are still outside Thailand. However, setting FAST LPR in critical road network nodes along the borderline is one of the best available ways to safeguard Thailand's borderline areas.

### 3. Myanmar (Burma)

In Myanmar, the situation is not so promising. The CIA reports that Myanmar is the world's second largest producer of illicit opium, and both the cultivation and the production are increasing. These increases are attributed to "lack of government will to take on major narco-trafficking groups and lack of serious commitment against money laundering."[54] Also, the country is a "major source of methamphetamine and heroin for regional consumption."[55]

The UNODC concurs with the CIA's general findings as well as future projections. As the Myanmar representative to the UNODC, Shariq Bin Raza puts it as follows:

> The sustainable elimination of opium poppy cultivation is a long term and complex process. One of the keys is consistency in government and international commitment. However, even with these there may be some periodic reversals in trend. This year[56], the cultivation in Myanmar has experienced such a reversal…This year's growth in cultivation should be looked upon as a serious warning against complacency.[57]

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[54] "The World Factbook: Burma," CIA, https://www.cia.gov/library/publications/the-world-factbook/print/bm.html (accessed August 16, 2008).

[55] Ibid.

[56] 2007.

[57] *Opium Poppy Cultivation in South East Asia: Lao PDR, Myanmar, Thailand* (New York: United Nations Publications, 2007), 49.

He also states that "Further hampering efforts toward elimination, the security situation in many opium producing localities is threatened by insurgents and traffickers."[58] As far as Myanmar's opium poppy cultivation is concerned, the following graph in Figure 6 visualizes the UNODC's data.

In Myanmar, like Thailand as well as the region in general, a reversal between 2006 and 2007 is evident.
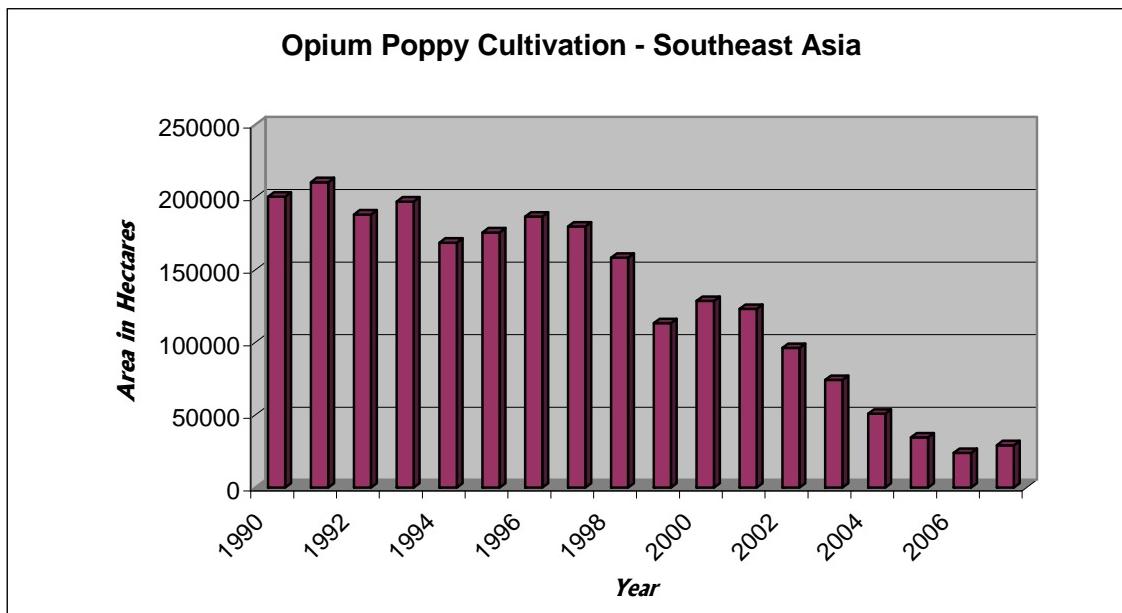


Figure 3.    Opium Poppy Cultivation in Southeast Asia[59]

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[58] *Opium Poppy Cultivation in South East Asia: Lao PDR, Myanmar, Thailand* (New York: United Nations Publications, 2007), 49.

[59] *2008 World Drug Report* (New York: United Nations Publications, 2008).
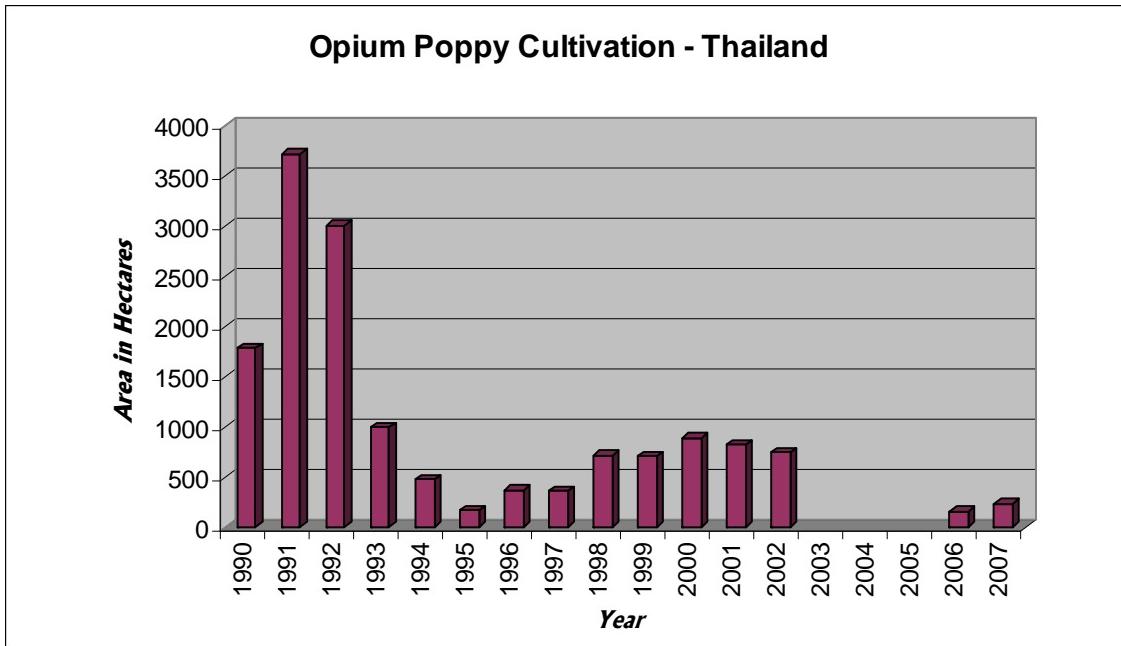
Figure 4.      Opium Poppy Cultivation in Thailand[60]
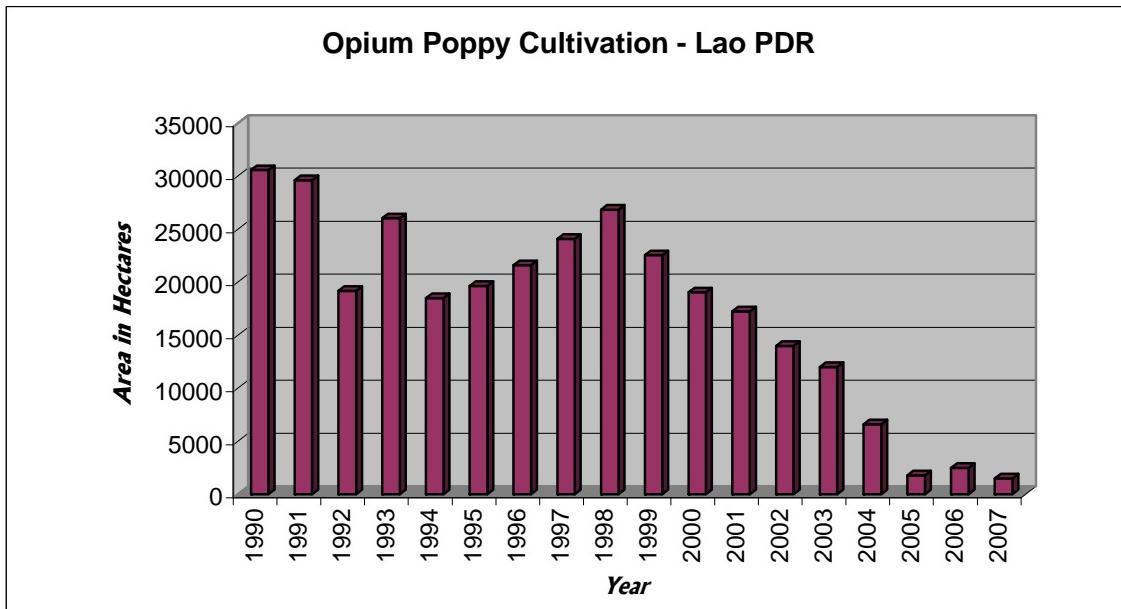


Figure 5.      Opium Poppy Cultivation in Lao PDR[61]

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[60] *2008 World Drug Report.*

[61] Ibid.

**Opium Poppy Cultivation - Myanmar**
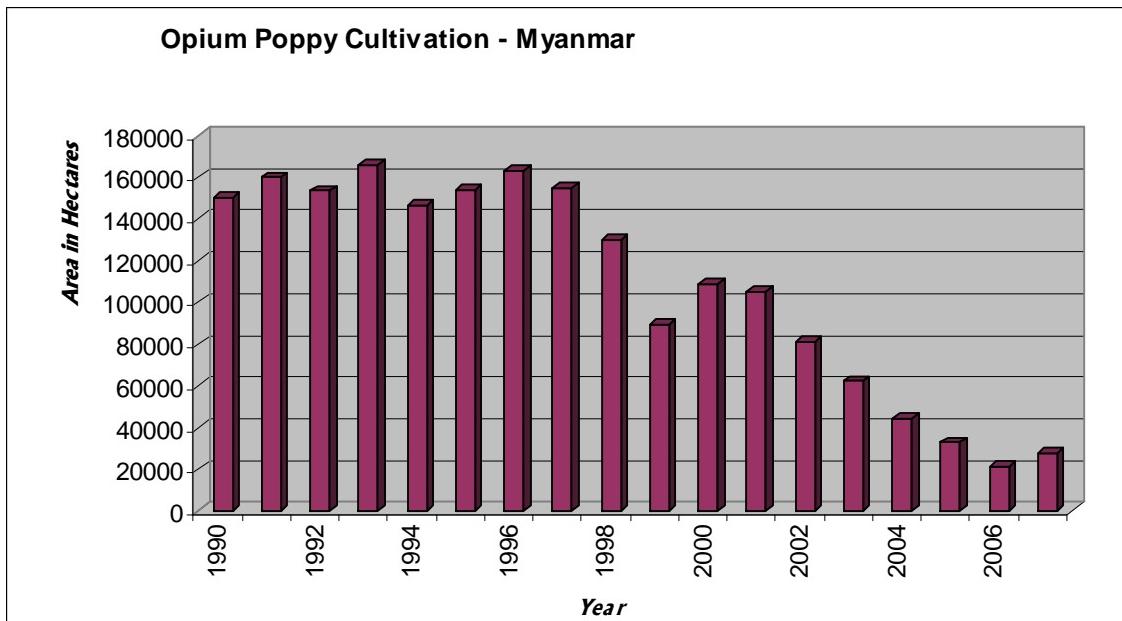
Figure 6.    Opium Poppy Cultivation in Myanmar[62]

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[62] *2008 World Drug Report.*

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# III.  NARCOTERRORISM

## A.    DEFINITIONS

Before describing the counter-narcoterrorism effort in the region, it is imperative to spread some light as to what narcoterrorism is and what it is not. Surprisingly, the term is a relatively new one. One of the most elucidatory definitions is the following:[63]

> The term *narcoterrorism* was coined in 1983 by Peru's president Belaunde Terry to describe attacks on the anti-narcotic police in that country. Even as use of the word has spread, experts are arguing about its definition. Some claim that narcoterrorism designates too broad a range of activities to be definitive for a particular form of terrorism. This entry will consider narcoterrorism to mean forms of terrorism that are linked to the production of illegal drugs, either through (a) the use of drug profits to fund political violence or (b) the use of violence and terror to protect and preserve illegal drug production.

This definition clearly highlights the reciprocal relationship between drug production[64] and terrorism that satisfies the needs of both participants, namely drug lords and terrorists. More emphatically, the interaction or the coexistence of these two elements becomes clear in the following:[65]

> These two purposes may overlap: a group using illegal drug profits to fund an armed political campaign will need to preserve the lawlessness and atmosphere of fear necessary for large-scale illegal drug production. Any large drug trafficking group will also need to influence the political climate of the country where it operates so that the general population fears the traffickers. Terrorism is effective in accomplishing these goals.

It is in Latin America where narcoterrorism was first recognized. Kushner states that "the Revolutionary Armed Forces of Colombia (known by its Spanish acronym, FARC) provides a typical example."[66] In that region, the main drug production is coca-

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[63] Harvey W. Kushner, Encyclopedia of Terrorism (Thousand Oaks, CA: SAGE Publications Inc., 2003), 251.

[64] And the subsequent illegal activities, such as illicit drug trafficking.

[65] Ibid.

[66] Harvey W. Kushner, Encyclopedia of Terrorism (Thousand Oaks, CA: SAGE Publications Inc., 2003), 251.

oriented. The nature of the local economy and the favorable conditions for coca cultivation, paired with the increased demand for coca products in North America, made coca a "cash crop"[67] for the Colombians. At the same time FARC was rising. Soon after, FARC managed to take control of some remote regions of the Colombian periphery. In the eyes of the local peasants, the authority they had to abide by was FARC instead of government forces. With FARC being in control of these areas, "it began to traffic in drugs."[68] FARC's revenue in the beginning was based on taxation on the drug loads as well as other crops like coffee, paid to them by the landowners. When FARC realized that the profit from coca taxes was incredibly higher than any other crop, they shifted from taxing the landowners to selling them protection in all phases - cultivation, market, and labs. Also, they were protecting "airstrips from government attack."[69] As Kushner concludes:

> For the narcoguerilla, the illegal nature of both the drug trade and the rebellion were complementary; untrammeled by national or international law, guerillas can openly offer traffickers their services, and traffickers are happy to pay richly for that protection.[70]

Latin America was the region of the world that opened the door to the emerging concept of narcoterrorism. The spread of narcoterrorism soon touched distant regions like Southeast Asia as well as other profitable paths like the Balkan route[71], the northern route, some of the former Soviet Union states, Iran, Pakistan, and so on. This "international" feature along with the reciprocity in the relation between traffickers and terrorists becomes clear by looking at the following extract from the U.S. Marine Corps Field Manual, "Combating Terrorism."

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[67] Harvey W. Kushner, Encyclopedia of Terrorism (Thousand Oaks, CA: SAGE Publications Inc., 2003), 252.

[68] Ibid.

[69] Ibid.

[70] Ibid., 251.

[71] Turkey-Bulgaria-FYROM-Albania.

*Terrorist Operations*: i. International Narcotics Support. Drug activities finance some terrorist groups. Terrorist groups may provide security for narcotics networks in return for financial support of their operations.

Perhaps the clearest way to describe the relationship –and its causality- between terrorist groups and drug business is the way General Tuan Shi[72] puts it:

To fight you must have an army, and an army must have guns, and to buy guns you must have money. In these mountains the only money is opium.[73]

In Southeast Asia, the most prominent narcoterrorist organization is the United War State Army (UWSA). "The UWSA has successfully asserted itself as the largest and wealthiest player in Myanmar's booming narcotics trade."[74] "The UWSA overshadows not only the smaller former communist ceasefire groups but also once-powerful ethnic factions such as the Kachins and Shans. UWSA ambitions have also made it a focus of security concerns for the wider region."[75] Regardless of the fact that the geographical location of UWSA's haven is Myanmar, the spill over effects impact the neighboring states, like Thailand.

The UWSA's dominance in the Myanmar-Thailand border is of vital importance for the Thailand's security. The problem of illicit drug trafficking is not a simple issue, because "narcotics trafficking is a serious social, political, and security issue for the international community."[76] Therefore, it affects not only the neighboring states, but the whole region as well. In many cases, the impact of the activities of strong narcoterrorist organizations can be widely spread across the world. Of course, the neighboring countries like Thailand are those that are the most affected by such illegal activities. Financially, the influx of drug money, especially in poor societies, is a factor leading to increased

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[72] General Tuan Shi-wen is a veteran of the covert wars in Burma.

[73] John Norton Moore and Robert F. Turner, *National Security Law* (Durham North Carolina: Carolina Academic Press, 2005), 175.

[74] "United Wa State Army (UWSA) (Myanmar)," Jane's World Insurgency and Terrorism, http://www.janes.com/extracts/extract/jwit/jwit0068.html (accessed September 1, 2008).

[75] Ibid.

[76] Alan Dupont, "Transnational Crime, Drugs, and Security in East Asia," Asian Survey 39, no. 3 (1999): 433.

corruption. Also, political instability is another problem that might follow, especially when the state is not able to provide the population with adequate services. Given this, narcoterrorist groups are able to consolidate their dominance among the population by offering them what the legitimate government can not. The end result is that the central government becomes discredited and the narcoterrorists appear to the impoverished locals as the only credible authority to lean upon. Such a community is the Mong Yawn Valley. "The UWSA has been developing a self-sustaining new community in the Mong Yawn Valley."[77]

UWSA in the mid-1990s started to shift from opiates to methamphetamine production. The chemical drugs are easier to process (produce and refine) and the required labs are smaller and less complex, hence more mobile than those required for morphine and heroin processing. This introduced another challenge for the counter-narcoterrorist forces - high mobility.

Thailand is affected by the illicit drug production in Myanmar by the fact that Bangkok (along with Hong Kong) "has become the corporate headquarter and key distribution center for the traffickers who control East Asia's drug trade."[78] Obviously, nearly all of Myanmar's illicit drug production has to find its way to Bangkok.

## B.    TRAFFICKING ROUTES

### 1.    Opiates

Based on the 2008 UNODC Report, "Trafficking in opiates continues along three major routes:"[79]

- From Afghanistan to neighboring countries of South, Southwest and Central Asia, the Middle East, Africa, and, in particular, to Europe.

- From Myanmar/Laos to neighboring countries (especially Thailand) of Southeast Asia and to the Oceania region.

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[77] "United Wa State Army," Global Security, http://www.globalsecurity.org/military/world/para/wa.htm (accessed September 1, 2008).

[78] Alan Dupont, "Transnational Crime, Drugs, and Security in East Asia," Asian Survey 39, no. 3 (1999): 449.

[79] *2008 World Drug Report*, 46.

Other important findings about the opiates trafficking are that "the majority of opiates continue to be transported along the Balkan route to Western Europe,"[80] and "some trafficking shifts to the Western Balkan route."[81]

### 2.    Cocaine

The main trafficking routes are geographically isolated from the southeast region.

### 3.    Cannabis

Cannabis seems to not be a very-often trafficked drug substance from/through Southeast Asia.

### 4.    Methamphetamine/Amphetamine, or ATS[82]

This is an increasingly worrisome area in Thailand. Whereas the opiates front appears to be relatively under control, ATS trafficking is increasing at a fast rate. Since these are chemicals, there are special requirements for the local authorities to track, locate, and positively identify ATS. This endemic difficulty results in forming new trafficking routes that "continue to develop in places that lack the enforcement and forensics infrastructure to detect precursor trafficking. These new routes have a wide geographical spread and include even Africa and West Asia, South and Central America, often starting from East Asia, or South Asia."[83]

The difficulty in locating the sources of laboratories initiating the production of these precursors is mainly because the required size of the labs is small, with no special equipment. The findings of the same report reveal that "clandestine ATS production is concentrated in North America, East & Southeast Asia, Europe, Oceania and Southern Africa,"[84] "tactics in clandestine manufacture changing,"[85] including change in

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[80] *2008 World Drug Report*, 46.

[81] Ibid.

[82] Amphetamine-Type Stimulants.

[83] *2008 World Drug Report*, 123.

[84] Ibid., 124.

[85] Ibid., 127.

trafficking routes. Top producing countries in the region for the period 2002-2006 were China (38%), Philippines (21%), Myanmar (21%), Thailand (6.4%), Japan (4.3%), and Lao PDR (4.3%).

It is important to note that "trafficking in ATS end-products remain primary intra-regional."[86] However, a greater cooperation takes place when talking about ATS precursor chemical trafficking, where "continues to be predominantly inter-regional-with the majority of precursors trafficked out of East, and Southeast Asia."[87] Globally, 62% of methamphetamine seizures in 2006 took place in East and Southeast Asia. This by itself is the best indication that ATS has been an increasingly important threat in Southeast Asia.

Among the major ATS trafficking routes in the region are:
- From Myanmar to Thailand
  - Directly
  - Via Lao PDR
  - Via Cambodia
- From Myanmar via Thailand to Malaysia, Indonesia, Singapore, and Brunei Darussalam.
- From Lao PDR to Thailand.
- From Cambodia to Thailand.
- From Thailand to Malaysia, to Taiwan province of China, and to the Republic of Korea.
- From Thailand to various other international markets.

Beyond any doubt, the above mentioned traffic routes place Thailand in a pivotal position in the ATS trafficking business.

## C. ROUTES THROUGH THAILAND

Regardless of the nature of the drug being trafficked, there are various different routes in Thailand that are often used. The vast majority of these routes, as seen in Figure

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[86] *2008 World Drug Report*, 137.

[87] Ibid.

7, cross the central region of the country, with many of them having the state capital of, Bangkok as a central hub. As The CIA states, "although heroin trafficking through Thailand has dropped in recent years due to tighter border security, the country remains a principal transit corridor and market for Burmese heroin and opium. Heroin moves overland through northern Thailand to Bangkok and southern Thailand for export by air and maritime conveyances."[88]
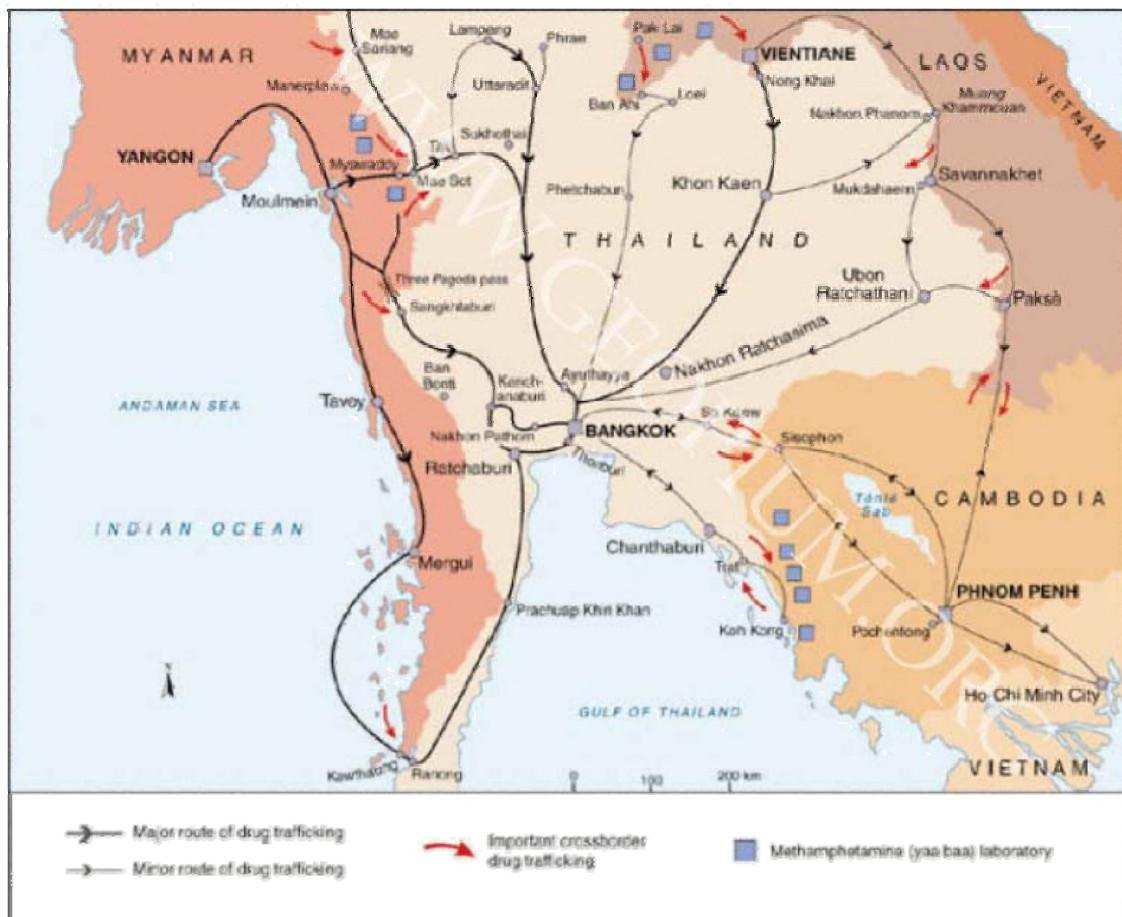


Figure 7.     Illicit Drug Trafficking Routes through Thailand[89]

[88] "Heroin Movement Worldwide: Southeast Asia," Central Intelligence Agency, http://www.cia.gov/library/publications/additional-publications/heroin-movement-worldwide/southeast-asia.html (accessed August 16, 2008).

[89] Pierre-Arnaud Chouvy, "New Drug Trafficking Routes in Southeast Asia," Jane's, http://www.geopium.org/JIR2.htm (accessed August 9, 2008).

Thailand is a critical node in the drug trafficking networks in the region of Southeast Asia. Especially in heroin trafficking, Thailand's prominence is often a result of unplanned events.

> Much of the heroin produced in the region reaches markets through southern China, although increased law enforcement pressure by Chinese authorities has forced some traffickers to seek new routes through Thailand.[90]

Another "route," the Mekong River, "remains a major conduit for heroin trafficking and is patrolled in only a few areas"[91] in Laos. Also, other areas are "virtually inaccessible." Nevertheless, the overland routes in Thailand are the preferred way for the drug traffickers to move their illicit product through Thailand, in order to reach either the final destination or the intermediate point for further export.

The fact that Thailand has overwhelmingly better road network (Table 1), port amenities, airport facilities, cargo terminals, and by far more cars being driven around the country (Table 2) is a critical reason for becoming the trafficking hub for illicit drugs flowing from Myanmar and Lao PDR as well as other places in the region.

| Country | Road Infrastructure (km) | | |
|---|---|---|---|
| | Paved | Total | % Paved |
| Cambodia | 1,500 | 34,000 | 4.41 |
| Lao PDR | 2,006 | 3,016 | 66.51 |
| Myanmar | 23,179 | 28,790 | 80.51 |
| *Thailand* | *50,279* | *51,544* | *97.55* |

Table 1.    Road Infrastructure in the Region[92]

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[90] "Heroin," Interpol, http://www.interpol.int/public/Drugs/heroin/default.asp (accessed August 22, 2008).

[91] Ibid.

[92] "ASEAN Yearbook 2005: Chapter VII, Transport and Communication," ASEAN, http://www.aseansec.org/SYB2005/Chapter-7.pdf (accessed August 1, 2008).

| Country | Total Vehicle Registration | |
|---------|-------------------|------------|
| | Vehicles | % in Region |
| Cambodia | 672,000 | 3.14 |
| Lao PDR | 187,000 | 0.88 |
| Myanmar | 424,000 | 1.99 |
| *Thailand* | *20,097,000* | *94.00* |

Table 2.    Number of Vehicles in the Region[93]

Taking into consideration the air transportation (Table 3), the picture is pretty much the same.

| Country | Number of Airports, 2001 | | | |
|---------|----------|---------------|-------|-------------|
| | Domestic | International | Total | % in region |
| Cambodia | 6 | 1 | 7 | 6.73 |
| Lao PDR | 11 | 2 | 13 | 12.5 |
| Myanmar | 21 | 1 | 22 | 21.15 |
| *Thailand* | *33* | *29* | *62* | *59.62* |

Table 3.    Number of Airports in the Region[94]

Of special importance might be the numbers of arriving/departing flights and the international passenger traffic for the four countries. For the year 1999, the international passenger traffic is shown in Table 4.

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93 "ASEAN Yearbook 2005: Chapter VII, Transport and Communication," ASEAN, http://www.aseansec.org/SYB2005/Chapter-7.pdf (accessed August 1, 2008).

94 Ibid.

| Country | International Passenger Traffic, 1999 | |
|---|---|---|
| | Passengers | % in the Region |
| Cambodia | 634,000 | 1.65 |
| Lao PDR | 160,000 | 0.42 |
| Myanmar | 521,000 | 1.36 |
| *Thailand* | *37,040,000* | *96.57* |

Table 4.    International Passenger Traffic in the Region[95]

For the year 1997, the number of departures for international destinations are shown in Table 5.

| Country | International Aircraft Departures, 1999 | |
|---|---|---|
| | Departures | % in the Region |
| Cambodia | 5,800 | 4.09 |
| Lao PDR | 1,400 | 0.99 |
| Myanmar | 3,300 | 2.33 |
| *Thailand* | *131,300* | *92.59* |

Table 5.    International Aircraft Departures[96]

Finally, as far as the air cargo is concerned, the data are shown in Table 6.

[95] "ASEAN Yearbook 2005: Chapter VII, Transport and Communication," ASEAN, http://www.aseansec.org/SYB2005/Chapter-7.pdf (accessed August 1, 2008).

[96] Ibid.

| Country | Cargo Loaded in metric tons, 1999 | |
| --- | --- | --- |
| | Cargo Load | % in the Region |
| Cambodia | 7,340 | 1.26 |
| Lao PDR | 35,800 | 6.16 |
| Myanmar | 5,450 | 0.94 |
| *Thailand* | *532,600* | *91.64* |

Table 6.    Cargo Load in the Region[97]

In addition, data for tourism in all four countries (Table 7) reveal that Thailand is by far the most favorite tourist destination in the region. This, aside from the financial boost that it gives to the local economy, makes the trafficking of illicit drugs easier for those who decide to move their drugs out of the region using Thailand as the gate out. On the flipside, the importance of tourism in the Thai economy is the soft underbelly as far as security is concerned, since the top tourist destinations are at the same time the potential hot spots for terrorist attacks.

| Country | International Tourist Receipt, 2004 | | | |
| --- | --- | --- | --- | --- |
| | Number of Tourists | | | % in the Region |
| | Intra-ASEAN | Extra-ASEAN | Total | |
| Cambodia | 183,000 | 872,000 | 1,055,000 | 7.35 |
| Lao PDR | 639,000 | 256,000 | 895,000 | 6.24 |
| Myanmar | 62,000 | 595,000 | 657,000 | 4.58 |
| *Thailand* | *2,937,000* | *8,801,000* | *11,738,000* | *81.83* |

Table 7.    International Tourist Receipt[98]

[97] "ASEAN Yearbook 2005: Chapter VII, Transport and Communication," ASEAN, http://www.aseansec.org/SYB2005/Chapter-7.pdf (accessed August 1, 2008).

[98] "ASEAN Yearbook 2005: Chapter VIII, Tourism," ASEAN, http://www.aseansec.org/SYB2005/Chapter-8.pdf (accessed August 1, 2008).

Beyond any doubt, Thailand is the most convenient exit gate country in the region for the illicit drugs being trafficked within the region of the Golden Triangle, or "consequently, Thailand has been considered the gateway for drugs coming directly from the 'Golden Triangle' and most of the Association of Southeast Asian Nations (ASEAN) countries are the transit points of the illicit drug traffic fro further distribution to the illicit market around the world."[99]

Thailand's superior road network renders the country the path of choice for the majority of illicit drugs produced in Myanmar and Lao PDR. Once the illicit drug loads enter Thailand, their flow through the road arteries leading to Bangkok or other transit hubs is easier. Most importantly, using vehicles that are merged with the rest of the traffic makes the trafficking through Thailand less risky, which contributes to lower prices. Hence, the drug lords' profit becomes bigger.

The traffic in Thailand is incomparable to the neighboring countries, and that makes the job of the counter-narcoterrorism Thai authorities along the roads much harder. For example, other reasons missing, Thai authorities stop vehicles for inspection at a random base. Statistically speaking, during the last few years there has not been a major drug load seizure along Thailand's roads, despite the fact that these roads are the main channel for the flow of illicit drugs.

FAST LPR will significantly help the Thai counter-narcoterrorism authorities better police their area of responsibility. Any vehicle that, based on their license plate and the database used, appears to be suspect will be stopped for further investigation, while leaving the rest of the traffic flow unimpeded. The system will be operational day and night regardless of the weather conditions, unlike the standard man-based road blocks. It is expected that the contribution of FAST LPR to the control of the illicit drug trafficking along the Thai road network will be critical.

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[99] Darwish Moawad, "Southernmost Thailand Violence: Illiteracy, Poverty, Politics, Illicit Drug Trafficking, Smuggling and Nationalist Separatists – not Religions and Cultures- the Issue" (presentation, UNESCO Conference, Melbourne, April 12, 2005).

# IV. COUNTER-NARCOTERRORISM

The basic question in the counter-narcoterrorism effort is who must be responsible for fighting the narcoterrorists: the military or the police. To get an answer to this fundamental question, one needs to deeply understand the nature of narcoterrorism and then figure whether the military or the police is the proper organization to deal with the problem. Since narcoterrorism involves drug trafficking, it seems that the police should be the force of choice to deal with them. Illicit drug trafficking is protected by terrorist groups, so, due to the terrorist element, law enforcement should be the appropriate organization to face the problem. The line becomes blurred, though, when we realize that the terrorists who protect–for profit–the drug trafficking are actually "small armies" that are equipped and trained more like a military. Their tactics are closer to insurgency ones, rendering the use of police against them rather ineffective. To cover their illicit drug trafficking, these terrorist organizations often hide behind facades like separatist movements, religious turmoil, and ethnic clashes, and that way, they manage to mobilize–on their side–part of the populace. Then, it becomes even harder for regular police alone, or the military, to cope with the situation.

> In many cases, crime and conflict are inseparable in so far as crime both serves to finance the strive and the strive provides the necessary opportunity structure for organized crime. One example for this is Myanmar, one of the world's leading providers of opium. Most of the drugs are produced in the mountainous areas primarily inhabited by ethnic minorities. Because the military government of Myanmar derives much of its legitimacy through restoring peace in the conflict-ridden country, the government and army has focused on negotiating ceasefire agreements, also at the cost of conceding autonomy to various ethnicities and ethnic organizations. This autonomy has enabled these organizations to cultivate opium without state interference, thus providing them with financial resources and in turn fueling the conflict feasibilities.[100]

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[100] Conflict Barometer 2007: Crises-Wars-Coup d'état-Negotiations-Mediations-Peace Settlements, 16th Annual Conflict Analysis (Heidelberg: University of Heidelberg Institute for International Conflict Research, 2007), 6.

The causality goes both ways, further supporting the reciprocal relationship between drug lords and terrorists, and in the case of Myanmar, this ends up being a spiral phenomenon in the sense that the profit reinforces the strength of the criminal organizations that in turn demand more autonomy, and so on. In Thailand, there is no evidence of such extreme variants of narcoterrorism, yet the spill over of the product of the drug lords in the neighboring countries into Thailand is important. Also, in the Thai southernmost regions, where a low-scale insurgency exists, it would be catastrophic to see such a spiral occur. British Broadcasting Company (BBC) reporter Kate McGeown describes the following:

> The police and army are still mistrusted by large sectors of the local, mainly Muslim community, and claims of unnecessary brutality are regularly made against them…There have also been allegations that security personnel have taken part in extra-judicial killings, partly fuelled by the case of Somchai Neelaphaijit, a prominent Muslim human rights lawyer widely thought to have been killed by police and government officials.[101]

The necessary "ingredients" are in place, namely the Muslim separatism, asking for autonomy, and terrorism is also present in the region. The slightest mishandling by the Thai government could be enough to spark further turmoil in the Muslim-dominated regions close to the borders with Malaysia. Especially during the recent period, the more acute the presence of the police or the army is, the worse the situation may become. On the other hand, there is no doubt that if in this region the law enforcement presence weakens, then in no time it will becomes a safe haven for drug traffickers and their narcoterrorist accomplices. Law enforcement has to equilibrate between acting under a low profile, as not to weaken black memories of the past or accentuate the dangerous situation, yet be effective; indeed, it is a very thin balance.

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[101] Kate McGeown, "Takbai legacy lingers in Thai South," BBC.co.uk, February 27, 2006, http://news.bbc.co.uk/2/hi/asia-pacific/4742976.stm (accessed September 2, 2008).

## A.    NATIONAL LEVEL

In the first half of 2007 in Thailand, 38 illicit drug loads have been seized.[102] These loads included a number of illicit drugs such as cannabis herb, cocaine, codeine, ecstasy, heroin, methamphetamine, opium, and chemical drugs. The majority of the places where the seizures took place were post offices or airports. There was no seizure that took place along the overland routes in Thailand.

During the second half of 2007, there were 98 reported illicit drug seizures,[103] an increase in the number of seizures of 157%. Again, there is no single seizure along the roads of Thailand. Rather, the seizures took place either in post offices or airports.

Data from 2007 reveals that, despite the findings mentioned earlier that the main route for the illicit drug trafficking through Thailand is the overland road network, surprisingly there is not a single seizure–out of 136 in total–along any of the country's roads. This is a paradox that highlights a major deficiency of the Thai counter-narcoterrorism orientation. An operational gap appears to be taken advantage of by the drug traffickers. However, to fill this gap Thai authorities need more than just reorienting their doctrine. The overwhelming traffic flow is not easily handled by the counter-narcoterrorism forces, in the sense that lacking any other piece of information, the vehicles will continue to be stopped on a random basis. Statistically speaking, the expected outcome is not so promising. The need to use some sort of "heads up" about which vehicles should be stopped for further investigation and which should continue their flow unimpeded is of vital importance. FAST LPR is exactly such a system, alerting the counter-narcoterrorism forces in a timely manner about suspect vehicles that go past a FAST LPR station, based on the license plate attached to the vehicle.

The system accuracy, aside from the technical characteristics that are described later on in this thesis, is heavily dependent upon the population of the databases utilized. At the national level, these databases are already in place among various governmental

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[102] *UNODC Bi-Annual Seizure Report 2007/1* (New York: United Nations Publications, 2007).

[103] Ibid.

organizations.[104] The operational link between these databases and the authority responsible for the operational exploitation of FAST LPR is something to be determined by the Thai authorities. Database population is an ongoing process in the sense that the record keeping is a dynamic procedure. Records of suspicious license plates is something that changes daily, and these changes should be reflected in the database manipulation. The more up-to-date the databases are, the more effective FAST LPR will be.

## B.    TRANSNATIONAL LEVEL

It is clear that no state alone can be efficient in the war against illicit drug trafficking. First, the nature of trafficking by default implies a border crossing. Second, since narcoterrorists often change routes as well as their whereabouts, it is critical for law enforcement to share information, or else every law enforcement authority will have to keep on reinventing the wheel. Lastly, when narcoterrorists take advantage of ethnic conflicts[105] in order to hide their dirty businesses behind the populace, the only way for the legitimate governmental authorities to pursue their goal is to give the impression that they act as a common fist against the drug lords and the narcoterrorist groups that protect them. Doing that, the risk for the illicit drug traffickers to continue their operations in the specific region will increase. Increased risk translates into need for extra security, and also into more loads being seized. The end effect will be less profit, and since profit makes the drug lords' world go around, these losses are not acceptable. The counter action will normally be a rescheduling of their operations, most notably including a rerouting of the drug loads through other conduits. For the law enforcement agencies of the cooperating countries this will be a battle won. One thing that is critical is the information sharing. Of special importance is to share frequent updates of the available databases used by FAST LPR. The more accurate and timely the information flow among countries, the better for the FAST LPR accuracy.

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[104] Thai police, Thai department of transportation, intelligence agencies.

[105] Especially near the borders between countries.

## 1.    Bilateral Cooperation

Thailand's geographical location is not the best pledge for any kind of bilateral cooperation. Based on the Freedom House report[106] for the world's most repressive societies, all Thailand's neighboring countries are considered "not free" (Burma/Myanmar, Lao PDR, and Cambodia) or "partly free" (Malaysia). In addition, Myanmar and Lao PDR are in the world's top twenty most repressive countries, with a downward trend. Nevertheless, since all four neighboring countries, along with Thailand, are ASEAN member states, all the agreements in security issues are within the framework of the various ASEAN committees.

However, an important bilateral cooperation between Thailand and the U.S. has emerged through the two countries' long history of cooperation. Along with military equipment and training that the U.S. military was providing to the Thai military, other aspects were also benefited, like intelligence cooperation. The importance of intelligence, or information sharing is already mentioned. The timely dissemination of pieces of information is vital for the counter-narcoterrorism authorities, in order for them to anticipate, rather than try to catch up with the events. Database updates regularly fed into the existing databases is the best guarantee that FAST LPR will be operating at its maximum capability, offering the counter-narcoterrorism authorities critical help in better policing their area of responsibility.

## 2.    Regional Agreements

The most prominent multinational organization in the region is ASEAN. ASEAN is already 40 years old and still struggling to become a cohesive body, which becomes obvious in Ong Keng Yong's Foreword in the organization's annual report for 2006-2007:

> It is also time for some introspection and for those of us in ASEAN to assess how ready we are, after four decades of evolution, to achieve our ambitious goal of becoming one ASEAN. By one ASEAN we mean a cohesive ASEAN community with one vision and one identity. From this,

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[106] *The Worst of the Worst: The World's Most Repressive Societies 2008* (Washington: Freedom House, 2008).

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we have spelt out more specific goals such as establishing ASEAN as a single market and promising ASEAN as a single tourist destination…Of note, we signed a counter-terrorism convention and concluded other important accords in the past year.[107]

Aside from the economic orientation, in the organization's agenda for the vision of 2020[108] for declaring the region as "drug free" is at a very high position. The ASEAN Ministerial Meeting of Transnational Crime (AMMTC), which established in 1997, recognizes that to meet its goal the states need to further broaden their efforts in exchanging information, sharing intelligence, establishing state jurisdiction, extending mutual legal assistance, and penalizing and criminalizing terrorist acts. In 2004, ASEAN's focus on counterterrorism effort was restated: "ASEAN leaders viewed terrorism as a profound threat to international peace and security and a 'direct challenge to the attainment of peace, progress and prosperity of ASEAN and the realization of ASEAN Vision 2020'."[109] The main orientation is towards "attaining the 2015 a drug-free ASEAN,"[110] which "continues to be a priority for ASEAN."[111] ASEAN is the main regional apparatus capable of fighting narcoterrorism by coordinating the states' actions that are agreed upon, and keeping states that do not fully abide by the terms of these agreements accountable. If a prosperous ASEAN region is the carrot, there is also the stick for the states that are not fully committed to the counter-narcoterrorism front.

### 3.    International Efforts

The legal framework for international cooperation, as well as countries' obligations, is within the UN. United Nations Office for Drugs and Crime is the central pylon in counter-narcoterrorism around the globe. Southeast Asia countries, due to their critical role in the global effort to win the war against drugs, are of special importance.

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[107] Secretary General of ASEAN.

[108] ASEAN's leaders agreed to shorten the target date from 2020 to 2015.

[109] Ong Keng Yong, "ASEAN's Efforts in Combating Terrorism and Transnational Crime" (speech, Second Asia-Pacific Homeland Security Summit and Exposition, Honolulu, November 16, 2004).

[110] Ibid.

[111] *Annual Report 2006-2007: Becoming One ASEAN*, (Jakarta, ASEAN Secretariat, 2007), 15.

The international community's war on narcoterrorism has two components. First is the obvious one, namely every possible measure to target the supply and demand of illicit drugs throughout the globe. The second component has to do with the financing of the narcoterrorists by cutting off the available channels for laundering the money from the illicit drugs. With money laundering procedures available to the drug lords, "the production and distribution of narcotics works around, and not through, legitimate economies, rendering them unsusceptible to sanctions committees."[112] Hence, any kind of sanctions simply do not work. Money laundering is the target of the second component of the international community's war on drugs.

Another critical mindset shift that is about to happen is the transition from "need-to-know" way of sharing information to a new concept, that of "responsibility-to-provide."[113] Indeed, information sharing emerges as the cornerstone of efficient counter-narcoterrorism operations, no matter what the scale of these operations might be. This information sharing has to be tailored to the context of counterterrorism itself. In addition, since narcoterrorism does not seem to bother with border issues, it becomes clear that information sharing also needs to go beyond the geographical limits of the sovereignty of any nation state. Thus, the counter efforts need to be international as well.

Of course, issues like the effective way to share information in a timely manner imply that the pieces of information are already collected and–after a first evaluation– they are to be disseminated properly. The techniques, mechanisms, and field systems dealing with information gathering as well as local processing is another component of the whole hierarchy of systems and procedures. One can say that the actual counter-narcoterrorism effort starts at exactly that point - field systems and applications. FAST LPR is one example of such system. The importance of timely sharing of information is already stressed earlier. Suffice to say that any system, like FAST LPR, is as good as the supporting elements, and in this context the database quality is crucial.

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[112] Ilias Bantekas, "The International Law of Terrorist Financing," The American Journal of International Law 97 (2003): 318.

[113] Part of the Track A: Land Security session, in the forthcoming 4th Annual Border Management Summit in Bethesda, http://www.BorderManagementSummit.com (accessed August 19, 2008).

## C.       THE ROLE OF TECHNOLOGY

### 1.       In General

The role of technology in history was always important. Technology was the driving force for innovative techniques, strategies, and tactics. He who was technologically inferior was in a disadvantageous position. The role of technology today is equally, if not more, important. With the advent of information technology (IT) and the continuous cost decline in IT systems, accompanied by the global spread of the Internet, it is easier than ever before to communicate around the globe as well as to control systems remotely, disrupt the normal operation of others' systems, and selectively deny services to legitimate users while giving access to non-legitimate users. Technology is a force multiplier for the terrorists all over the world, allowing them to decentralize their operations, and hence making it harder for the counterterrorism forces to locate, identify, and eventually sprain the forces of evil. However, technology is a double-edged sword, as it can be used the other way around, giving the counterterrorist forces advantages such as information gathering, manipulation, and exploitation. A good example of the use of technology to boost the operational ability of legitimate forces is the C4I[114] systems. Another relevant concept is network-centric warfare and various ideas about the in-theater implementation. Nevertheless, these concepts are just realizations of the various new capabilities that technology has to offer. It would not be too much to compare the changes that the invention of gunpowder brought to warfare with the not yet full potential that IT systems have to offer.

### 2.       Counter-Narcoterrorism

In this field, it seems that the narcoterrorists, in their attempt to maximize the profit they make out of the illicit drug trafficking business, was the driving force in taking advantage of the technological progress. Technology allows for the reduction of manpower that is required to achieve a task, offers unprecedented capabilities in the field

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[114] Command, Control, Communications, Computer and Intelligence. These are "systems that are designed to support a commander's exercise of command and control across the range of military operations and to generate information and knowledge about an adversary and friendly forces," Realizing the Potential of C4I (Washington, D.C.: National Academy Press, 1999), 1.

of communications, increases the chances for successful completion of illegal operations, and helps the narcoterrorists launder their dirty income easier and faster. Also, pushing funds around the world, often via multiple off-shore companies, became elementary and bypassed the economic sanctions that used to once be a big problem.

Early in this decade, and especially after the 9/11 attacks, people realized that narcoterrorism was a threat that had to be addressed immediately and that it was not a simple opponent. Narcoterrorism, in particular, was found to be connected in other terrorist activities.[115] It soon became necessary to reevaluate potential counter-narcoterrorism strategy. Yet many of the specifics of such a strategy are not finalized or not standardized globally, and one conclusion seems to be self-drawn: technology is the most critical ace in the hand of the counterterrorism forces.

Border control procedures had to change in order to adjust to the new reality, yet innocent people still had to continue to travel. A trade-off between security and the right to freely travel had to be done. However, no compromise in security was to be accepted given the tremendous shock of the 9/11 attacks. The ultimate way to make, for example, air traveling safe was to ground all the airplanes. These kind of measures, yet descriptive enough, are out of question, and it soon became clear that the only way to minimize the risk below acceptable levels was to take advantage of technology. In the air travel example, new screening devices were implemented, accompanied by personnel training. New smart video software started to be used to identify suspicious human activity in the air terminals.

Something similar signaled the need for counter-narcoterrorism: closing the borders simply was not an option. Even still, there would be the problem of illicit drug trafficking within the country itself. Stopping[116] all the cars along a major overland traffic artery might be the ultimate solution as far as effectiveness is concerned, but that kind of solution is not pragmatic. On the other hand, guessing or randomly choosing

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[115] With the most serious one being the funding of numerous terrorist organizations in the world.

[116] In order to extensively search the vehicles.

which vehicles to stop[117] and search was feasible, but the efficiency of such an approach was questionable. The idea of having an IT system that will help law enforcement personnel optimize their effort, by giving them clues, indications, or guidance on which cars appear to be suspicious, was the basic idea. Especially in countries like Thailand, with increased traffic and incomparably more vehicles than all its neighboring countries put together, such a system would help alleviate the workload of law enforcement and hence multiply their effectiveness, measured in number of seized vehicles trafficking illicit drugs without disrupting the rest of the traffic flow.

### 3.    CNTPO's Role

The very existence of the U.S. Department of Defense (DoD) Narcoterrorism Technology Program Office (CNTPO) manifests this shift in the mindset about addressing narcoterrorism using technologically advanced solutions. CNTPO is the offspring of the DoD Counter Drug Technology Development Program Office. The step forward from "Counter Drug" to "Counter-Narcoterrorism" was indicative of the new mindset against the illicit drug problem, recognizing that there was a need for a broader perspective than just doing "Counter-Drug" operations. This major step was taken in November 2003.

#### a.    *Mission*

The mission of CNTPO, as it is proclaimed on the first page of the November 2003 brochure of the office is *to develop and deploy technology that disrupts, deters, and denies narcoterrorist activities.*

The shift in the office, with the expanded goal was "a consequence of the changed national security environment, the shift in budget and other priorities in an evolving landscape of support requirements. The DoD will execute drug demand and supply reduction programs consistent with statutory responsibilities, presidential direction, and Department of Defense priorities."[118]

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[117] Which is the current practice in the region.

[118] U.S. department of Defense, Counter-Narcoterrorism Technology Program Office, Technologies That Make the Difference, November 2003, http://www.cntpo.com (accessed June 19, 2008).

The U.S. Department of Defense Counter-Narcoterrorism Technology Program Office (CNTPO) has the lead for developing technology for interagency and multinational operations to disrupt, deter, and deny narcoterrorist activities in an effort to reduce trafficking in illegal narcotics and materials that support global terrorist activities. The CNTPO provides all federal government agencies with a rapid response contracting vehicle that can award work quickly to support any counter-narcotics or counter-narcoterrorism operation or program anywhere in the world (domestic included).

By default, CNTPO's role is to deal with narcoterrorism. After various analyses about illicit drug trafficking in Thailand and ways to improve the effectiveness of local counter-narcoterrorism authorities, the disconnect between drugs being trafficked through the roads of Thailand and the total lack of drug loads seizures pinpointed the urgent need to address this issue. The idea of developing a system to assist the local authorities in better policing the road network, based on database records concerning suspect vehicles, led to the conceptualization of FAST LPR.

### b.    *COASTS and FAST LPR*

The field realization of an IT system that would help address the problem of in-vehicle illicit drug trafficking was assigned by CNTPO to the U.S. Naval Postgraduate School (NPS) Cooperative Operations and Applied Science & Technology Studies (COASTS) Field Experimentation Program. "COASTS provides a host of technical data management and surveillance technology support that has enormous applicability to the various threat scenarios the Thai government faces along its land and maritime borders."[119]

In particular, COASTS 08 field application in the counter-narcoterrorism arena is the FAST LPR system. The system was designed, developed, assembled, and field-tested in three major field experimentation (FEX) weekly events in the U.S.,[120]

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[119] U.S. Department of Defense, Headquarters of Joint United States Military Advisory Group in Thailand, *COASTS 2008 Correspondence*, September 14, 2007 (Thailand, 2007).

[120] Camp Roberts, CA, USA.

followed by two two-week international[121] field experimentation activities. In between these major field experimentations (FEXs), testing continued to take place in numerous areas[122] and extents[123]. The details for all the phases and the experimentation data as well as other technical specifics are presented in the following chapters.

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[121] Wing 5 Royal Thai Air Force Base, Prachuap Khiri Khan, Thailand.

[122] NPS campus, Fort Ord area, Monterey USCG station.

[123] The whole system, or specific subsystems or even particular components like IR cameras, visible cameras, IR illuminators, capturing computer, etc.

# V.     FAST LPR GENERAL DESCRIPTION

The increased transnational threat from narcotics, terrorism, and trafficking/smuggling is providing opportunities and impetuses for increased cooperation among partner nations in technology, information exchange, and shared responsibility for interdiction and law enforcement. The scale of the problem calls for reliable and cost-effective solutions with wide deployment to counter the widespread and asymmetric nature of the threats. FAST LPR offers one such solution set in the area of license plate recognition based on optical character recognition (OCR) that is reliable, cost-effective, and efficiently deployed across a global environment with a goal of supporting the urgent needs of friendly countries and organizations in combating the spread of narcotics, terrorism, and other trafficking crimes.

## A.     PRIMARY OBJECTIVES

The primary objective of this project is to create a low-cost, easy-to-use, proof-of-concept (POC) system to perform LPR accurately in a border checkpoint/perimeter security setting for the Thai character set. This POC must be efficient and capable of operation without significant degradation across a wide scope of conditions and locations, and be releasable to other partner nations. In order to create this POC system, the FAST LPR team had to:

- Test, evaluate, and establish performance limits/feasibility for standard LPR component configurations as well as extended component configurations and topologies.

- Develop a user/manager software interface, which is easily configured and operated, allowing for efficient integration of the base LPR algorithm and supporting the customers' (future) wide area network (WAN) connectivity requirements, including the security of U.S. to international connections.

- Allow easy entry of plates of interest (POI) that will alert an operator when that plate is recognized at a FAST LPR site.

- Develop a user friendly recovery disk to maximize the availability of the component/algorithm/software interface solution set.

- Create a stand-alone architecture.

**B.** **SECONDARY OBJECTIVES**

Secondary objectives consist of enhancing the performance of the base setup. This includes expanded optical testing with both covert and non-covert IR illuminators and the all light all night (ALAN) camera. Also included in this set of objectives is wireless connectivity to support distributed and remote installations, which can also optionally include field-ruggedized units for LPR capture. The FAST LPR solution can include analog and digital wireless strategies, along with a distributed LPR engine to GUI software architecture.

**C.** **FUTURE OBJECTIVES (FAST LPR 2)**

Future objectives consist of expanding the feature set of the base application. This can include a secondary LPR engine, vehicle identification and matching, and secure WAN connectivity for real-time or near real-time data interchange in a client-server architecture.

The basic solution set derived in FAST LPR will establish a methodology for rapid deployment and use of a variety of expanded video and analytical applications, which include non-OCR analytical applications such as:

- Behavior analysis – package take away, leave behind
- Motion – perimeter violation
- Biometrics – facial and skin texture, iris scanning, fingerprint
- Secure global database connectivity and data fusion

Built upon the same structure as the LPR engine, these new applications enable better analysis of the resulting information fused locally or remotely.

**D.** **PROJECT PHASES**

The overall project is comprised of the following phases:

- Phase 1

Research and define appropriate system elements (hardware and software) to achieve necessary LPR analysis with a commercial product for the Thai character set and have it be deployable for site conditions. Initiate equipment procurement.

- Phase 2

Research and define the LPR, GUI, and database requirements and feature set. Initiate the software programming project.

- Phase 3

Draft and finalize a concept of operations, test plan, and specifications/requirements guide.

- Phase 4

Strategic planning, design, and software development.

- Phase 5

Stage/configure system for hardware and software testing and evaluation as part of the Cooperative Operations and Applied Science & Technology Studies (COASTS) international field experimentation program in accordance with the schedule and locations shown below:

- October 2007: Project Planning Meeting #2 (Hong Kong)
- November 2007: COASTS Field Experiment (FEX) I (Camp Roberts, CA)
- January 2008: COASTS FEX II (Camp Roberts, CA)
- February 2008: COASTS FEX III (Camp Roberts, CA)
- March 2008: COASTS FEX IV (Rehearsal, Wing 5, Ao Manao Air Base, Thailand)
- May 2008: COASTS FEX V (VIP Demo, Wing 5, Ao Manao Air Base, Thailand)

- Phase 6

Final operational test and deliverables (deployment guidelines, system performance and configuration documentation, software deployment kit, and project report) provided to the project sponsor upon the conclusion of COASTS FEX V.

1. **Phase Details**

a. *Phase 1: Research and Define System Elements*

Potential applications and technologies were vetted to meet FAST LPR objectives. This includes the following:

- Confirmed character set capabilities (in particular Thai characters for the test deployment). Existing LPR engines support different character sets. North American vendors tend to support only Western character sets, so a search for a deployed and proven vendor was undertaken. Asia Vision Technology (AVT) was down-selected as the leadoff vendor for FAST LPR.

- Established current industry performance benchmarks for LPR. LPR algorithm vendors most often cite 95% recognition accuracy subject to the clarity and information content of the image and video stream characteristics.

- Determined operational limits of current technologies for both optical components and recognition engines. These factors include vehicle speed, angle of camera shoot, atmospheric occlusion/maximum camera distance, and headlight glare/blooming. Also affecting performance is the use of reflective plates in a jurisdiction where IR cameras have an additional advantage.

- Established a feasible requirement for the system architecture and topology. Included in this are the requirements for the LPR algorithm host processor, a trigger mechanism to initiate capture and camera resolution, sensor technology, and environmental capabilities of these components. Investigate feasibility of prospective wireless connections for remote or distributed deployments and system components for distance and covert image capture.

- Cross-checked the vetted technology elements with multiple LPR technology vendors to establish a confidence level in the system definition.

### b.      *Phase 2: Research and Define System GUI and Database*

The GUI and database research activities include:

- Performed research of existing LPR deployments to understand typical implementations to include envisioned functionality driven by project objectives. Analyzed and coupled with research from existing Department of Defense (DoD) human interface standards and vendor-specific algorithm software development kits (SDKs) and capabilities to arrive at an initial specification.

- Investigated database compatibility with DoD or law enforcement standards. The structure incorporates forward planning for customer compatibility, performance, and functional growth.

- Engaged in an interactive discussion of the draft specifications with the customer to refine the specification in order to begin design activities. Interactive discussion included the implementation of an easy setup/recovery process.

### c. Phase 3: Create CONOPS/System Requirements and Specifications

The project team has been researching LPR solutions for the past year, including solutions exceeding current limits for distant LPR image capture. The resulting efforts have defined the general FAST LPR concept and formed a basis for pre-selecting vendors and supporting technologies.

Initial project research as described above was coalesced with the full body of pre-project research to generate the FAST LPR configuration to meet initial deployment requirements in Thailand as well as during the international COASTS field experiment environments in California and Thailand.

The test plan itself used both simulated traffic (Camp Roberts) and real traffic (Ao Manao, Thailand) to ensure a wide sampling of the Thai character set (44 letters and 10 numbers) in conditions anticipated at deployment sites as well as higher speed testing to establish the performance envelope of the deployed system. Deployment site research itself requires a research effort that prioritizes for specific conditions though the program is designed for a superset of any specific site conditions.

### d. Phase 4: Strategic Planning, Design, and Software Development

This phase of activities includes the detailed experimental procedures to collect the test data and logistics (such as material shipping, cars, locations, power, etc.). Concurrent with this is the design and coding of the FLPR application in preparation for the first field test.

### e. Phase 5: System Staging and Field Tests

As described previously, there are five stages of field experiments from November 2007 through May 2008, testing progressively the various stages and capabilities of the product.

### *f.*     *Phase 6: Acceptance Tests*

Once the CONOPS is completed, a full-fledged acceptance test will be developed with the concurrence and collaboration of the end user.

### 2.     Scope

The basic focus is on the tools required for completing the primary objectives of phases 1 through 6, providing a plan for accomplishing secondary objectives, and designing for future growth in the area of user interface, wireless architecture, WAN connectivity, synthesis with general surveillance tasks, and additional video analysis.

Specifically, an analysis engine for LPR for the current project using a software-triggered capture algorithm will be configured, evaluated, and optimized into the flexible architecture GUI. Secondary objectives (if resources and time allows) will include extended range capture with IR illuminators (including visually covert units), off-angle image capture, distributed capture, distributed database, and GUI functions using wireless connectivity.

## E.     PURPOSE

CNTPO contracted the Kestrel Technology Group to develop a solution (FAST LPR) that meets the DoD Counter-Narcoterrorism Technology Program Office (CNTPO) mission for a quickly-deployed, algorithm-independent LPR application. Kestrel applied its expertise in advanced surveillance video technologies to interface with market-proven LPR engines, which in turn interacted with an LPR algorithm-independent GUI coupled with a local database and a planned WAN database interchange.

Kestrel selected AVT's LPR algorithm for use in the initial implementation. The multi-lingual capable AVT LPR algorithm includes the Thai language, selected for its wide support of character sets, defined performance envelope, and established field installation base. Character sets for future applications include English, Chinese, Japanese, Korean, Portuguese, and Spanish.

A3IT Solutions applied its expertise with enterprise network architecture to create a GUI/database combination that allowed for efficient reconfiguration to accept any number of LPR engines with little incremental software development while maintaining a consistent intuitive user interface and WAN database connectivity,

## F.    KEY CONCEPTS

### 1.    FAST LPR

The concept of Flexible Architecture, Sensors and Topology evolved from the CNTPO LPR mission, which is to efficiently deploy an LPR application that easily leverages the most effective character recognition engine available for a given character set. Due to the broad theater of CNTPO operations, an additional requirement was the adaptability of all system elements to the wide variety of conditions encountered. This includes processing nodes (computers), interconnectivity options (cables, wireless, and transmissions), sensors (cameras, triggering devices, illumination), and data.

Thus, the project has the following areas of focus pertaining to adaptability:

- Flexibility: of or pertaining to multiple character sets, languages, locations, and environmental variables

- Architecture: LPR algorithm-independent operation with effective WAN capability

- Sensors: Imaging and data acquisition components including near and distance image capture, vehicle and biometric data acquisition, and overall site surveillance

- Topology: System layout capability to support image capture remotely (distributed) from the GUI operation, localized "toll booth" type deployments and hybrid layouts of the two as dictated by conditions

This is the FAST LPR concept – to provide a readily deployable solution for almost any conceivable site requirement using the most effective algorithm available. The total solution incorporates software coupled with a pre-tested hardware set and a knowledge base of components and configurations for optimal performance.

## 2. FAST LPR Application (FLPR)

An important component of the FAST LPR POC is the creation of an overall software application based upon a local architecture for the POC, but then migrated to a WAN-based solution. The LPR application will be a Microsoft Windows™ based application that should be familiar in behavior to end users of this application that have worked with other traditional Windows™ applications.

This FAST LPR Application (FLPR - pronounced flipper) will consist of three main subsystems (Figure 8):

- Graphical user interface (GUI)
- Local database (Phase I)
- LPR algorithm wrapper for later additions of other OCR engines

The main goal of FLPR is to enable end users of the application with easy identification of vehicles of interest using a consistent user and system interface. This interface hides the complexity of the entire camera license plate recognition process and delivers an actual alert and action for a user or other operator to take. FLPR accomplishes this by using human factors engineering techniques that promote an intuitive low-learning curve interface.

Another objective is to support localization of end users to their native language through the interface and application settings for each user station. A primary goal of the architecture is to allow for future extensions of other LPR algorithms and capture mechanisms that can easily integrate into FLPR.
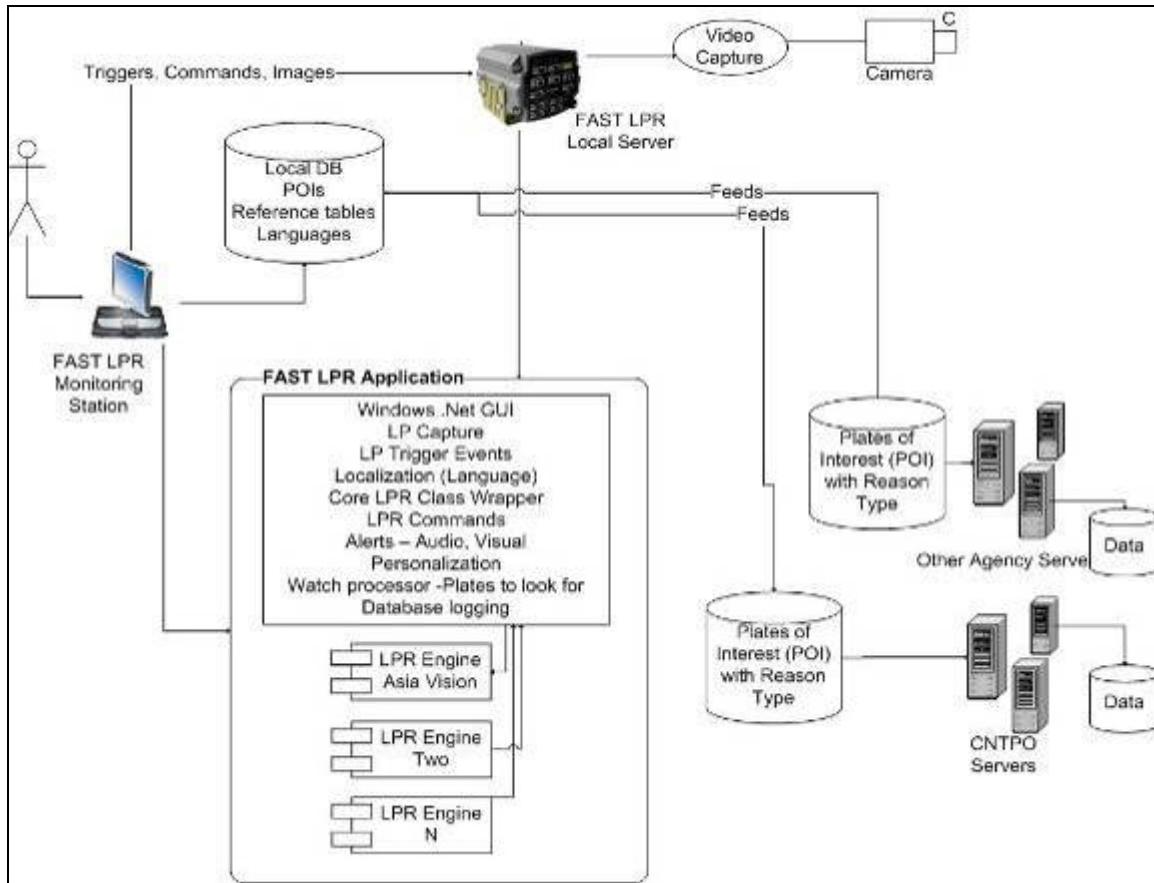
Figure 8.     FAST LPR Main Subsystems

### a.     Graphical User Interface (GUI)

Although in most cases for end users the GUI is "the system," it is in reality one of many components in a complex system such as FLPR. It is intended that the GUI for this application provide the end user with timely information, alerts, images, and actions to take as events occur. The main objective is to be able to initialize the LPR component at startup and receive captured images of automobiles and license plates as they approach the checkpoint area. Along with these images will be the actual license plate characters obtained from the OCR process. As a plate is recognized, FLPR "looks up" the set of characters of the plate in a local database of suspect plates–a "watch list"–and issues an appropriate alert to the end user station. The alert can be a text and/or an audible alert simultaneous to the event.

The GUI is comprised of various sections or windows (tabs) appropriate to the function at hand, such as real-time video streaming, static capture of automobile and license plate for an alarm, and the actual alert messages. A separate frame can be used for surveillance cameras that are IP-based cameras.

Main Tab - areas on the main page will consist of the following: a live video stream of vehicles focused on the plates for the capture routine, a static image window for still shots of plates that have been recognized, a live video stream from a camera focused on passengers within the vehicles, an alerts message area, a running list of plates and times of vehicles that have passed along with collateral information such as date/time, number of vehicles that have passed, and a general notification text area.

Topology Tab – Using internet connectivity, by selecting the topology tab the user will see satellite imagery and road maps as needed by the user.

Settings Tab – this tab will allow for modification of global configuration variable settings if needed in the field without requiring software development changes.

As future business requirements are flushed out, other sections or windows will be added as needed to meet those requirements. Lastly, another key feature of the GUI will be administration windows to allow the end user to add plates to the watch list, update alert messages, and perform any other administrative tasks identified during the analysis phase. A separate tab within the application, i.e., a settings tab, is included to set and update various settings on the fly as needed for each installation of FLPR.

The GUI that Asia Vision Technology uses is Super Robo Eye as shown in Figure 9.

Figure 9.     Asia Vision Technology Super Robo Eye GUI

When FAST LPR recognizes the license plate properly and compares it with the entries of the databases, there are various options. When the license plate is registered in the database as "authorized" (white list), then the computer provides the operator the screen shown on Figure 10. If the vehicle is an unauthorized or suspicious one, then the recognition result window has the form of Figure 11.

Figure 10.    Authorized Vehicle



Figure 11.    Unauthorized, or Suspect Vehicle

### b.       *Database (DB)*

For Phase one of the project, the database consists of a local version only, with plans to extend it to multiple locations over a WAN. The database for FLPR is comprised of tables that store information (such as reference tables) for alert messages, language translations, and data about what plates to watch for, which triggers the alerts to the end user.

Along with application-specific data further defined in the design and development phases, the incorporation of security IDs and roles into the DB, in addition to historical capture information such as location and date and time of when the license plate capture occurred, is included. Critical configuration information for the application will also be contained in the DB allowing for necessary real-time parameter changes.

It is the intent in a future phase to this POC to incorporate automatic updates in the form of system-to-system interfaces from key enforcement agencies. This additional feature allows the triggering of available alerts on a global scale.

### c.       **LPR Algorithm Wrapper**

Initially, FLPR will deal with only one LPR engine, the Asia Vision VECON-VTR. Within the design, the plan is to enable the ability to add additional LPR engines without any impact to the end users' view or interaction with FLPR. Each additional OCR integration will most likely require a point release to update the base application since other LPR engines will have different SDKs required to interface with that particular engine.

An LPR class or "wrapper" within the application will allow users to easily extend and accommodate other LPR engines without noticeable changes to the user interface. This wrapper will be the control mechanism interacting with the engines to initialize and capture video and plate information used for the alerting process.

### 3.       **Sensors/Cameras**

The key element for LPR image capture is contrast. The stronger the demarcation between the light background of the plate and the dark letters (or vice versa), the easier it

is for an algorithm to recognize the relevant area of an acquired image for character recognition. Many countries (including the U.S. and Thailand) employ nighttime reflective plates to improve the ease of readability at night from oncoming headlights, etc. These plates increase contrast and thus aid the LPR process.

IR (infrared) sensor-type video cameras work especially well with reflective plates as these plates reflect IR wavelengths. Furthermore, IR illuminators, being out of the visible spectrum, can be used both at night and during daylight with minimal or no effect on passing motorists. This allows for an augmented capability versus the visible spectrum to read plates at night in difficult atmospheric conditions (rain, smog) or with some degree of occlusion like dirt on the plates. For these reasons, IR cameras are the preferred solution for LPR with reflective plates.

The other alternative is visible spectrum cameras for well-lit areas. These can be used in locations where non-reflective license plates are used, or at very well-lit areas such as large toll plazas. When used for LPR, color charged-couple device (CCD) cameras with a wide dynamic range (high contrast) are one solution as they are better suited to deal with headlight blooms at night than ordinary CCDs. Color CCD cameras can also be a companion to IR LPR for vehicle identification when using color as a data element. In vehicle surveillance, very low-light color cameras (such as the Kestrel ALAN camera) deliver individual characteristics in varying vehicle light and can provide effective overall site surveillance in a variety of lighting conditions during both day and night.

### 4.    Processors

Commonality, compatibility, and ease of use mandate the use of a Windows® processor. The AVT engine, which is typical of LPR algorithms, specifies a Pentium IV 3.0 GHz processor or better. Newer laptops running Intel Duo-Core processors can equal this performance and provide a mobile alternative for development and rugged, fast-deploy installations such as ad hoc checkpoints. Rugged laptops such as General Dynamics Itronix and Panasonic Toughbooks represent new units that can run LPR algorithms in outdoor conditions.

Fixed site alternatives include high temperature, extended burn-in industrial units that are rack mountable. These laptops are the preferred solution, though practical experience indicates more conventional office-type servers and towers can be used.

The rugged industrial computers and laptops are also the solution of choice for distributed topologies where the capture camera and computer are located remotely from the GUI location and placed in a National Electrical Manufacturers Association (NEMA) -type enclosure (Figures 12, 13 and 14) that can include environmental control. Integrated all-weather CPUs as used by tactical/military forces are also deployable for FAST LPR.



Figure 12.    FAST LPR Case

Figure 13.　FAST LPR Case Connectors



Figure 14.　FAST LPR Case Components

## 5. Topology

Figure 15 illustrates the topology of the FAST LPR system as part of the facility protection architecture.
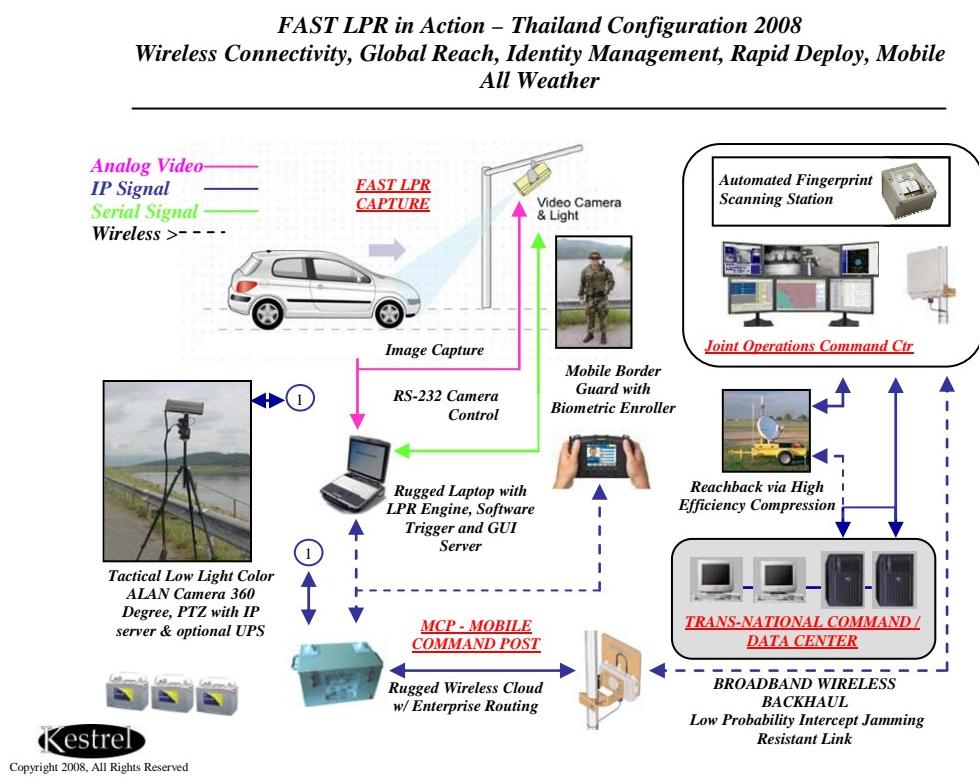


Figure 15.    FAST LPR Topology

## 5. LPR Algorithm Engine

The LPR algorithms employ optical character recognition that is used on images to recognize license plate numbers. The cameras used can include existing road-rule enforcement or closed-circuit television cameras as well as mobile units with cameras typically attached to vehicles. Some systems use infrared cameras to take a clearer image of the plates.

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Typical software requires the following six primary algorithms for identifying a license plate:

- Plate localization – responsible for finding and isolating the plate on the picture
- Plate orientation and sizing – compensates for the skew of the plate and adjusts the dimensions to the required size
- Normalization – adjusts the brightness and contrast of the image
- Character segmentation – finds the individual characters on the plates
- Optical character recognition
- Syntactical/geometrical analysis – check characters and positions against country-specific rules

The complexity of each of these subsections of the program determines the accuracy of the system. During the third phase (normalization), some systems use edge detection techniques to increase the contrast between the characters and the plate backing. To reduce the visual "noise" on the image, a median filter may also be used.

The software must be able to cope with a number of possible difficulties. These include the following:

- Poor image resolution, usually because the plate is too far away, but sometimes resulting from the use of a low-quality camera
- Blurry images, particularly motion blur
- Poor lighting and low contrast due to overexposure, reflection, or shadows
- An object obscuring (part of) the plate; quite often a tow bar or dirt on the plate
- A different font, which is popular for vanity plates (some countries do not allow such plates, eliminating the problem)
- Circumvention techniques

A typical neural network-based algorithm block diagram is shown in Figure 16.
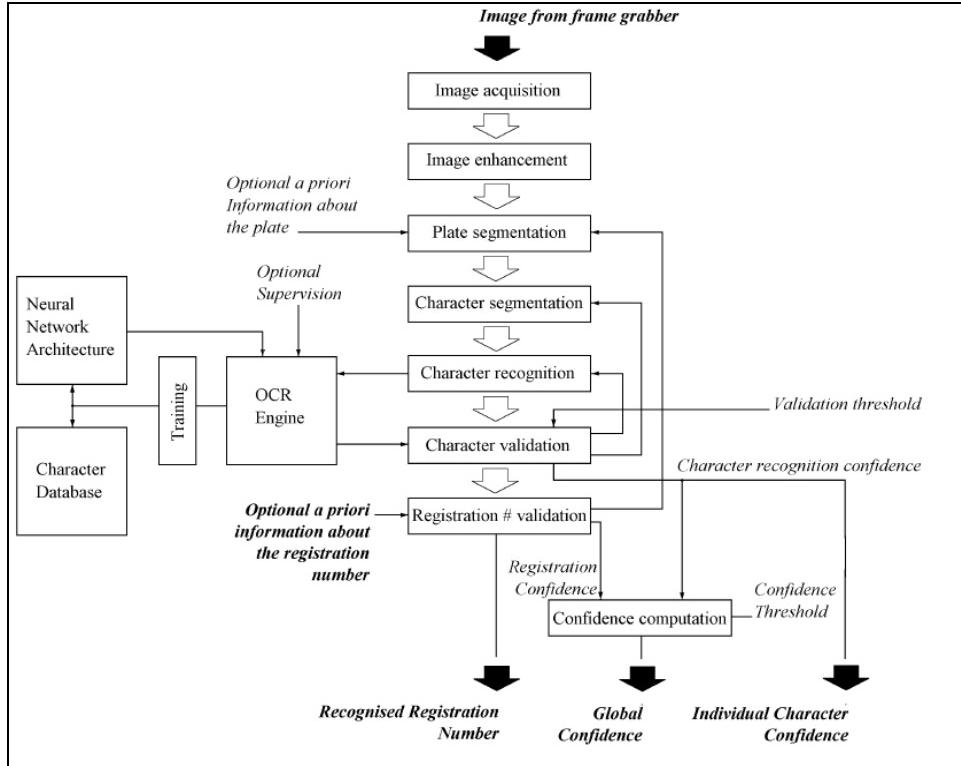
Figure 16.    Typical Neural Network-based Algorithm Block

FAST LPR implements an automatic character extraction/recognition algorithm that efficiently and accurately locates characters from complex images of license plates.

The images may be complex due to a variety of reasons, such as the following:

- the characters may be embedded in other objects
- the characters may be painted in colors which may be sometimes indistinguishable from the background color
- the font size and the format of the characters may be entirely different such as Thai license plates versus North American license plates
- the lighting may be uneven
- the speed and the motion of the cars may blur the images significantly

A typical character extraction process is comprised of the following steps:

- Threshold selection
- Detection of character right boundary

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- Components character extraction connection
- Post processing, which is usually comprised of aspect ratio computation, contrast histogram, and run length measure

## G.    SYSTEM REQUIREMENTS

### 1.    LPR Algorithm

#### a.    *Performance*

Performance of the LPR algorithm is affected by the following:

- Ambient lighting (day and night)
- Plate quality (reflective material enhances contrast)
- Plate occlusion (dirt, damage)
- Atmospheric occlusion (smoke, dust, rain)
- Local light interference (auxiliary illuminators and headlights)
- Camera shooting angle in both the vertical and horizontal plane
- Relative motion of camera to vehicle motion, proportion of plate image in overall image, distance of camera to vehicle, and the algorithm performance for a given character set

For widely deployed market algorithms such as those by AVT, the recognition accuracy is given at the limits, or implied limits, of many of the factors listed above. The Thai character set is characterized by most, including AVT, as the most difficult of LPR character sets, yet AVT cites 95% recognition with a clean license plate at the appropriate magnification lighting and focus.

Current advertised distance limits for LPR are up to 120 feet with high-power IR illuminated cameras. These figures come from camera vendors and not LPR algorithm providers. Long distance shots in particular suffer from atmospheric occlusion such as smoke, smog, and rain (rain can debilitate the application). Likewise, skew angle (angle of shoot) tolerance varies from vendor to vendor with AVT specifying up to 20 degrees (including the Thai character set) and other vendors claiming 5 degrees tolerance, but up to 97% recognition at elevated speeds (English character set).

Compressed video (such as MJPEG, MPEG, etc.) can compromise image quality, so the LPR recognition accuracy is specified for uncompressed video. For this specification, standard distances, speeds, and shot angles will be employed with extended parameters being tested as secondary objectives. FAST LPR should attain 95% accuracy under the following conditions:

- Daytime
- Night (IR Illumination aided)
- Up to 50 MPH (verify recognition latency / vehicle throughput capability)
- 20% horizontal x 5% vertical plate content in captured analysis image
- Full Thai character set (main letters w/reflective plates)
- 10 degrees maximum skew angle
- 30 feet maximum camera-to-vehicle distance
- Software trigger on front side
- Acceptable plate occlusion
- D1 resolution camera
- Uncompressed NTSC or PAL video signal to the capture computer

### b.    Configuration

The configuration requirement for the LPR basic algorithm must allow for access to the data generated from plate recognition as a data stream. This permits merging LPR data on an algorithm-independent basis into the FLPR GUI. For many applications, this is routinely accomplished using an SDK. SDKs consist of commands and variable calls that can be accessed by a high-level programming language (such as C sharp, .net) to create the custom interface.

The command set must also include a means to archive data for the image, plate recognition data, and video streams or series of plate shots. Statistics such as confidence or probability measures should be accessible and multi-language capability is convenient though not essential, as accomplishing that requires software updates to the GUI.

The algorithm should be capable of initiating video capture (trigger) by a hardware device or software analysis. Hardware triggers such as loop coils (installed under road) have very good reliability, operating at 99% or better notification. Other devices are pressure tubes and photo sensors. Software triggers are less reliable, missing as much as 5% of cars, but are convenient for rapidly deployed or mobile platforms. To accomplish the primary objectives of FAST LPR, FLPR utilizes a software trigger and the data is adjusted accordingly.

The following is a list of SDK data calls:

- LPR numerical value w/time
- Adjustable number of frames per trigger event
- Image
- Video archiving for vehicle forensics (future)
- Recognition statistics (i.e. analysis confidence, etc.)
- Support software (current) and hardware (future) trigger

## 2. Software Requirements Specification (SRS)

This SRS addresses the primary objectives of the FAST LPR architecture, to include the graphical user interface and initial database design, to support a local proof of concept. FAST LPR needs to be able to support multiple LPR algorithms from possibly different vendors while requiring only incremental software changes to be integrated.

The first generation system employs video triggering where license plate number (LPN) recognitions matched against potential watch list plates alert the end user of the system in real time through both visual and audio cues. The initial phase only utilizes a local database near the actual capture site, although system design accommodates a distributed global framework in subsequent release versions after the proof of concept (POC). The system goal is to employ best practices in the design of the GUI to ensure that the interface is user friendly and intuitive. Capabilities for remote administration will be included.

FLPR will be a Microsoft Windows-based application that is developed in VB.Net, Microsoft .Net Framework 3.0, and SQL Server 2005 to leverage the latest available technological advancements available.

### a.    GUI/Features

The system shall have an administration subsystem that will enable an authenticated user to perform the following tasks associated with maintaining key information relating to LPR along with reference table maintenance:

- Add, modify, and delete system users
- Add, modify, and delete alert messages; having customizable alert messages and sounds for different alert types
- Add, modify, and delete language translations
- Check User authentication

The system shall support image capture from video signals with the following specific capabilities:

- Include live video for real-time monitoring
- Recognize license plates appearing in the video frame
- Employ the video triggering mechanism for capturing passing vehicles
- Handle single lane for the POC
- Provide both black list and white list (list code) to suit different application usages including alarm actions and responses
    - For ease of hot list management and maintenance, the import/export hot list features are provided
    - In addition, the hot list can be updated via the GUI or by network messages from a remote control center for instant update
- Instantaneous display of captured vehicle image along with its respective recognized license plate number (LPN)
- Store both captured images and recognition results in a file system and database for later retrieval or export
- Allow a user to modify the recognized LPN and append remarks to each individual vehicle record for further auditing and reference purposes
- Implementation of security levels for various actions

- FLPR system designed for follow-on efforts such as the ability to search vehicle records in real time by specifying a combination of search criteria such as time, LPN, color, location, and alert type.

### b. *Software General Features*

The following are general characteristics of the FAST LPR software:

- Designed to support alternative LPR components (i.e. support a translation wrapper for integration and class extensibility)

- Support multi-platform distributed LPR recognition and GUI

- Support manual compare/alarm database local load

- Support secure WAN database upload/download (future)

  - Remote multi-server connections

- Support multi-language changeover (Thai and English)

- Utilize best practices U.S. GUI design standards

  - Support for personalization of end user GUI preferences

  - Support for localization of end user preferences

- Database alarming on LPR compare

  - Recommended action

  - Plate number

  - Matching trigger record

  - Vehicle image

  - WAN alarm routing (future – cell, PDA, Internet)

- LPR data archiving

  - General ISR video archiving

  - Secondary objective: camera optimized for larger vehicle shot

    - long-term storage on alarming
    - short-term storage on all vehicles

- Recovery process

  - Software recovery feature – external disk or mirrored/RAID drives

  - GUI driven setup application

### 3. Hardware

The basic components and the way they are architecturally interconnected are shown in Figure 17.

**FAST LPR System Architecture**
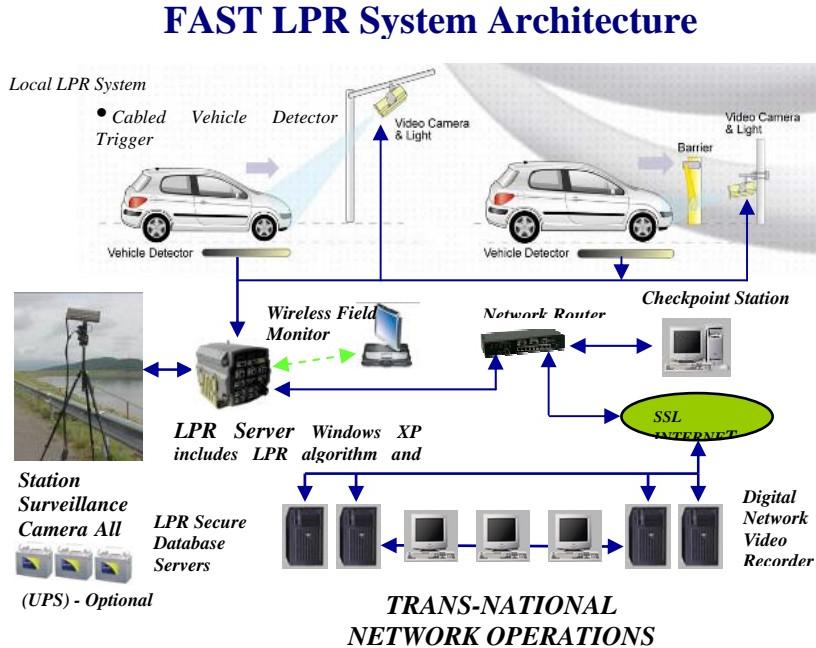


Figure 17.    Hardware Components and Architecture

### a. *Capture Cameras/Lenses*

The primary objective of establishing a reliable and standard deployable LPR solution will be met with an IR camera equipped with an illuminator. As earlier discussed, this high contrast solution is the established norm for high accuracy recognition rates where reflective license plates (as in Thailand) are used. The camera resolution must match or exceed that required by the LPR algorithm, which for the AVT product is D1 resolution. This is a full National Television Standards Committee (NTSC) U.S. picture of 720 x 480 pixels or Phase Alternating Line (PAL) Asian picture of 720 x 576 pixels. The camera lens must also have a manually set iris (preferred) or auto iris control capability to adjust for changing light conditions. An auto iris control uses an auto iris lens that can be too slow to respond to changes in light such as that provided by vehicle headlights. It is best to have a stable exposure optimized for the site setup;

fluctuations are not desirable. To freeze vehicles at any speed, requires a minimum shutter speed of 1/1000 of a second. Also desirable is a serial camera control parameter link to remotely adjust exposure, shutter, etc.

Visible light spectrum cameras may be necessary where plates are non-reflective and the added element of color enhances the LPR recognition, or when used as a vehicle or individual identification device. High dynamic range CCD cameras and/or backlight compensation controls increase the ability to see in shadowed areas and deal with ambient point source light (headlights, etc.). Specifications for high dynamic range cameras vary greatly from just over 100 to as high as 170 db. Like many video parameters, these numbers are subjective and must be tested by the end user in a deployment environment.

The system must be usable at all hours and throughout the year, so an appropriate housing such as an IP55 housing or better/equivalent is required. IP55 housings resist penetration of both water and dust and thus allow operations in almost all conditions. Extremely hot climates may require temperature controlled housings; this has to be established for Thailand-based testing.

The common lens requirement for LPR is for a fixed lens operation in most cases. The precise setup to capture a properly framed and focused image at any speed requires optimal settings for focus and magnification as well as a stable mounting. Therefore, auto-focus and motorized zoom lenses can be superfluous as these functions will go unused in most applications. It will be necessary to have a day/night lens. These lenses have multi-contoured elements that can direct visible and IR spectrum wavelengths to the same precise focal length. This results in a setup that does not need to be refocused at night when using an IR illuminator that is also used in a daytime setup, when the IR camera operates in the visible spectrum.

One of the secondary project objectives is to conduct tests with extended performance optics; these may include solutions involving focus adjustments for day and night as well as other lens/exposure strategies including distance. The lens precision or "quality" requirement will increase with distance, potentially requiring conducting trials with different lenses before making a selection.

- Camera specifications

  - Minimum D1 native resolution

    - 720 x 480 (NTSC) / 720 x 576 (PAL)
  - 1/1000 shutter speed or better

  - IR capable or high dynamic range sensor

  - Backlight compensation

  - Electronic iris or external auto iris (electronic iris with manual lens preferred)

  - Serial link for camera control (optional)

    - Iris (electronic)
    - Shutter
    - Field exposure
  - IP55 enclosure or equivalent

- Lens

  - Manual focus capability (non-autofocus mode)

  - Fixed or manual zoom/varifocal

  - Manual (preferred) or auto-Iris

  - Day/night optics (for IR sensors)

  - Magnification to produce 20% horizontal by 5% vertical plate image

- Illuminator choices – wavelength must match sensor capability

  - 30 ft (standard)

  - 60 ft (covert distance)

  - 90 ft

  - High-power (distance TBD)

### b.     *Capture Computer*

This computer is essentially a portable or laptop computer that runs on the Windows XP Professional operating system with the following characteristics and requirements:

- Weatherized housing (field/remote)
- Encrypted wireless (field/remote)
- USB 2.0, Firewire or PCI slot
- Serial input
- MS Windows® XP Professional
- Gigabit Ethernet (main station/all in one)
- 600 MB storage (main station/all in one or extension)
- P4 3.0 GHz or higher (@ 1.8 GHz Duo Core)
- Video RAM TBD

### c.     *Surveillance Station Camera*

The surveillance station camera provides a broad area picture of the FAST LPR site for vehicle and personnel recognition purposes. This camera should have the following characteristics/requirements:

- Weatherized housing
- All light / all night (ALAN) capability
- Remote PTZ and focus
- Manual focus capability (non-autofocus mode)
- Telephoto lens
- PAL/NTSC output
- 1/1000 sec shutter speed or better
- Serial link for camera control
    - Iris (electronic)
    - Shutter
    - Field exposure
- Automatic exposure control
- Backlight compensation

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# VI. TEST REQUIREMENTS

## A. FAST LPR TEST SCOPE AND OBJECTIVES

### 1. Test Scope

The scope of this test plan focused on testing and demonstrating the capability of the FAST LPR system fielding the AVT LPR engine, Kestrel cameras, the A3IT-developed GUI, and commercial technologies such as computer networking components.

### 2. Test Objectives

The main objectives that the NPS Team adhered to were as follows:

- Collect at least 100-200 images of 20-30 Thai license plates under a variety of conditions such as

  - Daytime

  - Night (IR Illumination aided)

  - Vehicle speed up to 50 MPH

  - 20% horizontal x 5% vertical plate content in captured analysis image

  - Full Thai character set (main letters w/reflective plates)

  - 10 degrees maximum skew angle

  - 30 feet maximum camera-to-vehicle distance

  - Acceptable plate occlusion

  - D1 resolution camera

- Quantify and document the LPR accuracy during the various stages of development. Include techniques such as placing similar characters next to each other on the plate.

- Identify errors/bugs/requirement mismatches and unrealistic conditions as to how close the systems meets/exceeds the desired accuracy of 95% and under what limitations.

## B. TEST PROCEDURES

Once the proof of concept for FAST LPR is complete, a detailed specification for the test procedure will be developed, outlined, and carried out during the various test phases. Techniques will be developed and employed to facilitate experimental runs.

### 1. Test Protocol

#### a. *Thai License Plate*

(1)     Samples. The Thai license plates provide a rich variety of challenges in terms of license plate recognition such as:

- Thai character shape
- Background color of the license plate
- Background images of provinces
- Small characters specific to provinces

See Appendix B for a variety of samples of Thai license plates

(2)     Background Images of Thai Provinces: Specific Characteristics of Thai license Plates. Plates are currently embossed in aluminum, black on reflective white, with the serial number in western characters, prefixed by a Thai letter, along with the provincial name (also in Thai) centered across the bottom of the plate. Officially, issued plates have a lightly stamped seal in one corner of the plate. Interestingly enough, homemade plates without the seal are also known to be in existence.

- Motorcycles have a smaller black on reflective white plate, with the province on the top part of the plate, instead of the bottom
- Hotel cars and buses have black on green colored plates
- Taxis, trucks, and commercial transport vehicles have black on yellow plates
- Heavy trucks and buses have very large plates, in black on white or yellow, with the following code numbers in the bottom right corner of the plate:
    - 10-19: represents a commercial bus
    - 20-29: represents a small bus

- 30-39: represents a tour bus

- 40-69: represents a private bus

- 70-79: represents a commercial truck

- 80-99: represents a private truck

- Diplomatic vehicles have black on white plates, with a special Thai prefix letter

- Consular, International Mission/Organization and Non-Diplomatic Embassy staff vehicles have white on blue plates, with a special Thai prefix letter

- Military vehicles have white on black plates, with a special symbol prefix:

    - A "throwing star" for Royal Thai Army

    - An "anchor" for Royal Thai Navy

    - A set of "wings" for Royal Thai Air Force

    - A combination of the three symbols for combined forces

- Police vehicles have silver or cream on metallic or enamel red plates, with a "sword and shield" crest to the left of a number

- Temporary plates are black on red, with "Bangkok" in Thai across the bottom

- Truck Dealers have white on red plates, with "Bangkok" in Thai across the bottom

(3)     Use of Thai Consonants on License Plates. The license plates will be chosen such that they will have at least two occurrences of very similar Thai consonants as shown below in Table 8.

| No | Thai Character Consonants | Very Similar Thai Character |
|:---:|:---:|:---:|
| 1 | ข *kho khai* (egg) | ฃ *kho khuat* (bottle) [obsolete] |
| 2 | ค *kho khwai* (water buffalo) | ฅ *kho khon* (person) [obsolete] |
| 3 | ช *cho chang* (elephant) | ซ *so so* (chain) |
| 4 | ฌ *cho choe* (bush) | ญ *yo ying* (woman) |
| 5 | ฎ *do cha-da* (headdress) | ฏ *to pa-tak* (goad) |
| 6 | ฒ *tho phu-thao* (old person) | ณ *no nen* (novice monk) |
| 7 | ด *do dek* (child) | ต *to tao* (turtle) |

| No | Thai Character Consonants | Very Similar Thai Character |
|----|---------------------------|----------------------------|
| 8  | น *no nu* (mouse)         | บ *bo baimai* (leaf)       |
| 9  | ผ *pho phueng* (bee)      | ฝ *fo fa* (lid)            |
| 10 | พ *pho phan* (tray)       | ฟ *fo fan* (teeth)         |
| 11 | ฤ *ro rue (short)* *      | ฤๅ *ro rue (long)* *       |
| 12 | ฦ *lo lue (short)* *      | ฦๅ *lo lue (long)* *       |
| 13 | ษ *so rue-si* (hermit)    | ส *so suea* (tiger)        |
| 14 | อ *o ang* (basin)         | ฮ *ho nok-huk* (owl)       |

Table 8.    Similar Thai Consonants

### b.    *Lighting Conditions*

The lighting conditions will be pre-determined for each test. The tests will be conducted at least once during day and once during the night for each trial period. The actual available light will be monitored and recorded with a Lumens meter for each test and trial condition. A challenge will be to run the same tests in dusk and/or dawn, since for many combinations of Visual/IR sensors these lighting conditions have their own difficulties. Especially for the IR cameras, another critical factor could be the so-called "thermal crossover," which in many cases renders the IR sensors (those at the thermal range of IR) incapable of providing the required image quality. Thermal crossover is easily encountered in areas with extreme temperature differences between day and night (i.e., the desert)

### c.    *Cameras*

Each test will be conducted with specific cameras. The initial cameras scheduled for testing will be the standard Asia Vision Technology camera along with the more technologically advanced Kestrel ALAN camera.

### d. Distance Between Camera and Vehicle

The experiments will be designed such that the distance from the camera to the vehicle license plate is a specific predetermined value. Possible distance selections are 25, 50, 100, and 200 feet.

### e. Vehicle Speed

Design the experiments to measure the impact of vehicular speed on system accuracy. The test vehicle will conduct sufficient trials at the following speeds: 5, 20, 40, and 50 miles per hour.

### f. License Plate Occlusion

Since the license plate on an actual vehicle is subject to road grime and other debris, conduct tests with partially occluded license plates with specially made plastic covers that will not transmit or diffuse light.

### g. Weather Conditions

As a deployable system, globally varying weather conditions must be accounted for. The experiments in California will provide opportunities to conduct tests and trials in the presence of condensation (fog). The experiments in Thailand will afford tests and trials in the presence of rain (the May timeframe is the beginning of the monsoon season in Thailand and thus torrential rains are possible). As mentioned above, in desert areas the visually disturbed atmosphere could pose another threat against the minimum required image quality, since the images can be blurry.

### h. Terrain Type

Monitor and record the type of road terrain to ascertain whether smooth pavement or rough terrain influences the system accuracy due to vertical or horizontal blur (stemming from the vehicle driving through and around potholes, bumps, etc.).

### i. Background Color and Color Combinations

As discussed earlier, the background color of the Thai license plate (see Appendix A), coupled with the multitude of color combinations, may have impact on the system accuracy. Experiments will be conducted to verify the effect of background color on LPR accuracy.

### j. License Plate Placement

The actual placement of the license plate (left, right, or the middle) on the vehicle bumper (or lack thereof) may also affect the system accuracy. Consequentially, tests and trials will study the system variation amongst the different possible license plate placements.

### k. License Plates with Identical Alphanumeric Strings but from Different Provinces

It is possible that a Thai license plate will have an identical alphanumeric string but belong to a different province as evidenced by the smaller letters on the bottom of the plate. Also, since specific provinces have unique and different backgrounds Appendix A), it is possible to use that information to further differentiate the license plates and thus improve accuracy.

Table 9 depicts all the possible variables of the experiments and the choice of parameters.

| No. | Factor affecting LPR accuracy | Parameter | Values | |
|---|---|---|---|---|
| 1 | Lighting Conditions | Bright Sun Light | Dawn or Dust | Night |
| 2 | Cameras | AVT | ALAN | L1 |
| 3 | Distance between Camera and Vehicle | 25 feet | 100 feet | 200 feet |
| 4 | Vehicle Speed | 5, 20 miles | 40 miles | 60 miles |
| 5 | License Plate Occlusion | None | Very Little (10%) | Partial (40%) |

| No. | Factor affecting LPR accuracy | Parameter | Values | |
|-----|-------------------------------|-----------|--------|---|
| 6 | Weather Conditions | Normal | Rain | Fog |
| 7 | Terrain Type | Smooth Pavement | Hilly Terrain | Sandy Road |
| 8 | License Plate Background Color | Dark | Light | Medium |
| 9 | Placement of License Plate | Left | Middle | Right |
| 10 | License Plate from Different Provinces | Same Province | Different Provinces | |

Table 9.    Experiment Values

## C.    PERFORMANCE MEASURES FOR LICENSE PLATE RECOGNITION

For the purposes of testing the FAST LPR system the same performance measures being used for any biometric system apply – the system accuracy rate. While this rate is critical, "asking a system to perform 100% accurate, 100% of the time" is clearly unachievable. Machines are prone to inaccuracy, just as the human beings using them are. The users of a system must decide what is reasonable to the system considering the environment as well as what purpose the biometric is applied to. Therefore, this project will examine how the system performs as it pertains to the errors in the system and the overall accuracy of the system

### 1.    Errors

A License Plate Recognition System must deal with two types of error, namely false rejection rate (FRR) and false acceptance rate (FAR). The rate at which these errors occur is a critical part of measuring a system's performance. The false acceptance rate is the probability that an unauthorized license plate is authenticated. The false rejection rate is the probability that an authorized license plate is inappropriately rejected. The equations shown in Figure 18 calculate both rates:

$$\widehat{FAR} = \frac{\text{number of false acceptances}}{\text{number of impostor attempts}} \qquad (1)$$

$$\widehat{FRR} = \frac{\text{number of false rejections}}{\text{number of enrollee attempts}} \qquad (2)$$

Figure 18.    Equations for FAR and FRR

Figure 19a demonstrates the balance between the false rejection rates and the false acceptance rates using a receiver operating characteristic (ROC) curve. A ROC Curve "is a plot of FAR against FRR for various threshold values for a given application. An example of an ROC Curve is shown in Figure 19, in which the desired area for a given application is at the lower left of the plot, where both types of errors are minimized."[124]

When a system has a high number of false acceptances, it will ultimately have less security. If the system has a high number of false rejections, it will offer less convenience. Figure 19a demonstrates the difference using a receiver operating characteristic (ROC) curve. The point at which the number of false rejections equals the number of false acceptances is known as the equal error rate (EER).

Another way to measure accuracy is a variant of the ROC curve known as detection error tradeoff (DET). The DET curve takes the same tradeoff as the ROC curve, but it uses a normal deviate scale. Essentially, this takes the same data and moves it away from both the X-axis and Y-axis, which allows for greater readability when plotting multiple curves. Figure 19 depicts the two curves side by side.

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[124] U.S. Naval Postgraduate School, COASTS, FAST LPR Requirements and Specifications 1.5.0, 2008 (Monterey: 2008), 47.
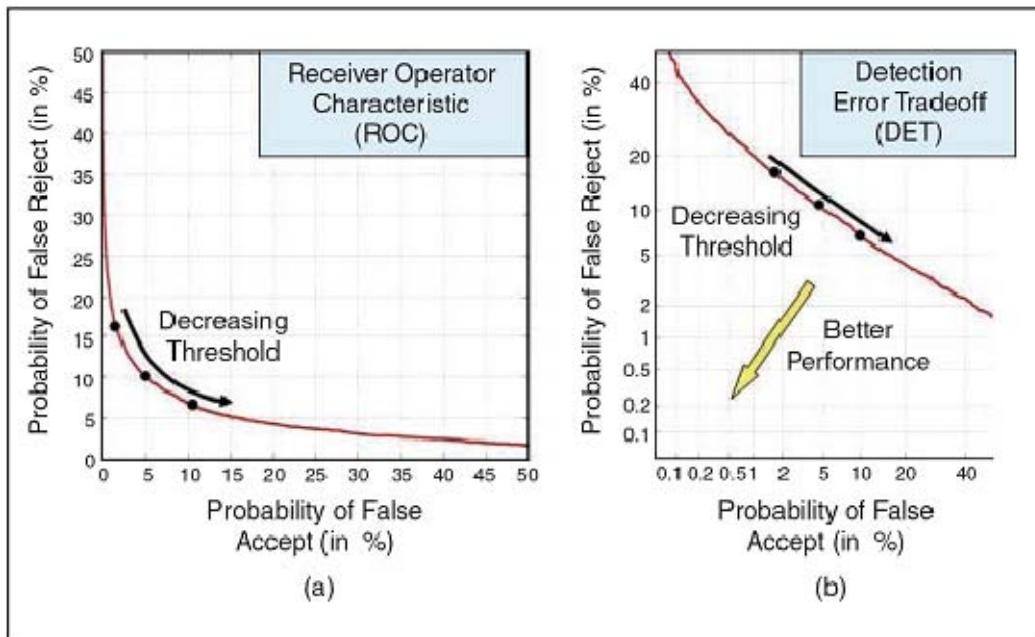
Figure 19.    ROC Curve and DET Curve

Remember, these terms refer to the performance of the system, not necessarily the overall accuracy of the system, although there is a degree of correlation. The system accuracy has more to do with a single point analysis.

## 2.    Accuracy

As stated previously, accuracy is the ability to detect the license plates correctly. The accuracy, however, may vary depending on the actual test conditions, which need to be tracked and reported. Mathematically, the true accuracy of a system is measured in relation to a single data-point analysis. In order to get this, the following equation must be used:

$$NT = NTAR + NFRR + NFAR + NTFR.$$

where,

|      |                                                  |
|------|--------------------------------------------------|
| NT   | The total number of valid verification attempts  |
| NTAR | The total number of true accepts                 |
| NFRR | The total number of false rejects                |

NFAR    The total number of false accepts

NTFR    The total number of true failures

Therefore,

 Accuracy of the System = (NT - (NFRR + NFAR)) / NT = (NTAR + NTFR) / NT

### 3. Confidence Interval

  Although a point can provide a good reference for accuracy, it does not reflect the confidence that given the same experiment the same point would be determined (repeatability). Estimating statistical parameters, such as mean or variance from a set of samples, can result in "point estimates." Point estimates are single number estimates of the parameters in question. While very useful in many applications, one limitation of a point estimate is the fact that it conveys no idea of the uncertainty associated with it. If many such point estimates are used in the same analysis, it can become challenging to decipher which estimate is the best or most accurate.

  On the other hand, a confidence interval provides a range of numbers (between a lower limit and an upper limit) with a certain degree of probability as to the possible interval of the respective point estimate. Thus, it is easier to conclude that the point estimate with the shortest confidence interval is the most robust and reliable.

### 4. Sample Size Discussion

  For the purpose of this study, it is assumed that the accuracy of the LPR system is 95%. The confidence intervals for various sample sizes are provided in Table 10 below.

| Sample Size | Confidence Interval |
|:---:|:---:|
| 50 | 6.04% |
| 100 | 4.27% |
| 250 | 2.70% |
| 500 | 1.91% |
| 1000 | 1.35% |

Table 10. Confidence Interval

If the system error is 5%, we would like the confidence interval estimate to be half of that, around 2.5%. This means at least 250 independent (samples) trials are needed. Assuming five trials per license plate means at least 50 license plates are needed. High volume sampling can also accomplished at on-site locations in Thailand, where large volumes of regular traffic can be captured and analyzed. This is the case at FEXs IV and V at Ao Manao, Thailand.

### 5. Controlled & Uncontrolled Variables of the FLPR Experiments

In Table 9, the author has provided 10 variables, each with at least three possible combinations. If the author was to perform an experiment which tests all these possibilities he would need 59049 trials (3 to the power of 10) – too many to conduct. This implies that he may have to use some controlled variables whose values are predetermined based on prior or smaller experiments, and certain uncontrolled variables whose values will be allowed to vary.

In Table 11, the author separates the controlled and uncontrolled variables and limits the choices to two per variable and not three as defined previously.

Out of the 11 variables for the initial experiment, the author will select seven as controlled variables. For three of them he will have two choices of parameters. This provides 9 possible experiments (3 to the power of 2), and with each experiment having at least 50 trials this leads to a total of 450 samples overall

| No. | Factor affecting LPR accuracy | Parameter | Values | Variable Type |
|---|---|---|---|---|
| 1 | Lighting Conditions | Bright Sun Light | Night | Variable with a set of possible values |
| 2 | Cameras | AVT | ALAN | Variable with a set of possible values |
| 3 | Distance between Camera and Vehicle | 100 feet | | Controlled Variable with preset values |
| 4 | Vehicle Speed | 40 miles | | Controlled Variable with preset values |

| No. | Factor affecting LPR accuracy | Parameter | Values | Variable Type |
|---|---|---|---|---|
| 5 | License Plate Occlusion | None | | Controlled Variable with preset values |
| 6 | Weather Conditions | Normal | Rain | Variable with a set of possible values |
| 7 | Terrain Type | Hilly Terrain | | Controlled Variable with preset values |
| 8 | License Plate Background Color | Ignore the Color Information | | Controlled Variable with preset values |
| 9 | Placement of License Plate | Middle | | Controlled Variable with preset values |
| 10 | License Plate from Different Provinces | Ignore Province Information | | Controlled Variable with preset values |

Table 11.    Controlled and Uncontrolled Variables Affecting LPR Accuracy

## 6.    Test Scenarios and Individual Test Plans

Detailed test scenarios and plans will be prepared for each of the tests during the COASTS field experiments I-V as well as to account for the various geographic locations.

An initial test or series of tests will be conducted on a very limited set of data (10-15 license plates and 50-75 samples of license plate images) to validate the choice of controlled variables with the suggested parameter values in Table 11.

A baseline test will be performed with the AVT camera on the chosen database of 50 license plates and at least 250 samples of license plate images. For each license plate image the FLPR program will identify a miss or hit for a variety of pre-selected thresholds in order to generate the ROC curve. The overall ROC curve, based on 250 samples, will be generated and the FAR, FRR, and EER will be determined. The system accuracy will be computed at the EER as well as at the toe of the curve most optimal in terms of FRR.

The same data will be reanalyzed for a subset of samples for the various combinations of the parameter values, which did not have preset values. The EER, FRR , FAR and the system accuracy will be computed for these. The results will be compared with the baseline experiment with AVT and default values for all parameters to establish the variation in LPR system accuracy.

The same test procedure will be repeated during each phase of the test. The lessons learned and the performance measures will be documented and tracked throughout the life cycle of the project on order to improve the quality of the FLPR system to reach the goal of 95% accuracy in field experiments.

**7.     Test Schedule**

The test schedule is shown in Table 12.

| No | Description | Schedule |
|---|---|---|
| 1 | Test 1st Iteration | 11/01/2007 – 12/14/2007 |
| 2 | Test 2nd Iteration | 01/01/2008 – 02/01/2008 |
| 3 | Test 3rd Iteration | 02/15/2008 – 02/29/2008 |
| 4 | Test Final Iteration | 04/01/2008 – 04/15/2008 |
| 5 | Acceptance Test | 04/15/2008 – 05/30/2008 |
| 6 | Final Test Report | 05/01/2008 – 05/30/2008 |

Table 12.    Test Schedule

In addition, tests were conducted at the following locations:

- **November 2007:** COASTS FEX I (Camp Roberts, CA)

- **January 2008:** COASTS FEX II (Camp Roberts, CA)

- **February 2008:** COASTS FEX III (Camp Roberts, CA)

- **March 2008:** COASTS FEX IV (Thailand Rehearsal, Wing 5 Ao Manao Air Base)

- **May 2008:** COASTS FEX V (Thailand VIP Demo, Wing 5 Ao Manao Air Base)

## 8.      Test Resources

The NPS students will be the primary resources for conducting the tests. However, the LPR system will be installed at the gate of the test sites so that each car will be monitored and processed through the FLPR system. The operational details will be included in each specific test plan.

## 9.      Roles and Responsibilities

The NPS students, assisted by the faculty, will conduct the tests and evaluate and report the performance of the system. Kestrel Technology Group and A3 IT Solutions will deliver an integrated FAST LPR product and participate in setting up the test environment and collecting the test results. Asia Vision Technology will deliver the LPR technology engine and will be responsive to the needs of Kestrel and NPS in order to fix any problems or difficulties associated with the use of the LPR engine as well as the AVT camera.

## 10.      Review and Status Reports

After each test, there will be a detailed test report summarizing the results as well as highlighting the lessons learned.

## 11.      Issues and Risk Assessment

There are several risks for the success of the FLPR project. These risks need to be assessed early on and risk mitigation strategies properly planned to assure mission success.

- The FLPR system accuracy may be much lower than 95%. If this is the case this problem needs to be identified as early as possible. The following remedial actions also need to be taken:
  - Identify root causes
  - Identify limiting factors
  - Reduce/limit the scope of the experiments
  - Improve design or quality of hardware/software

- Conduct realistic experiments

- Manage customer expectations

- The database of 50 license plates and 250 sample images may not prove adequate. Initial assumptions are that these quantities are adequate. However, the NPS team will continue to increase the inventory of license plates throughout the project. Alternatively, the large sampling of plates available from real traffic streams in Thailand may be leveraged as a source of high count and randomized sample data.

  - The real challenge is to balance the need for adequate sample size to the ability to finish the experiments and analysis on schedule.

- The weather conditions at the various test sites may not be cooperative.

  - This is an uncontrollable event and the reason the NPS team is conducting several tests (at least three separate phases).

- The software may not become mature soon enough to provide reliable results.

  - The multiple phases of testing should minimize this risk as problems and bugs found early will be fixed sooner rather than later.

- The hardware may not function according to specifications.

  - These findings will be documented and corrective actions taken as soon as possible.

- NPS may not have enough test personnel to adequately perform the various tests at the various test sites.

  - Even though NPS students are primarily responsible for performing the tests, this project will augment the test personnel from other sources such as the Office of Naval Research reserve officer detachment.

- The project may overrun on budget and run late due to unforeseen circumstances.

  - The NPS team is cognizant of this possibility and regular weekly reports and assessments of the progress in consultation with the CNTPO program managers will minimize this risk.

  - Any challenges which are threatening to delay the project will be slated for future projects.

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# VII.  FIELD EXPERIMENTS (FEXS)

## A.    FEX I

Field Experiment I (FEX I) took place at Camp Roberts, from November 12, 2007 to November 17, 2007. The FAST LPR testing was done at the following two areas: the main entry/exit gate of the McMillan Airfield (simulating the gate scenario) and along the McMillan Airfield runway (simulating the roadside scenario).

- Goal/objective(s):

  - Day shot-taking, phase-looking for the optimal set-up geometry-wise

  - Fine tune the Asia Vision IR camera

  - Establish the analogue wireless FAST LPR dedicated link

  - Investigate the impact of the light coming out of the "target" car headlights to the image captured by the ALAN IR camera with and without the use of filters and low-power IR illuminator

- Goal/objective(s) completed during test:

  - Day shots taken. Good accuracy (correct recognition) in the speed range of 20-45 mph.

  - Established the analogue wireless FAST LPR dedicated link.

  - Impact of the light coming out of the "target" car headlights to the image captured by the ALAN IR camera with and without the use of filters and low-power IR illuminator investigated.

- Highlights of testing:

  - Wireless analog link establishment

  - Good accuracy with car speeds up to 45 mph

- Unresolved items:

  - Night shots using the ALAN IR were overexposed due to the opposing light stream from the car's headlights. Filters blocking visible light did not work as expected. The proposed solution is the use of a high IR illuminator along with a better lens (increased zoom distance) combined with the smallest iris setting possible. A more off-center axis geometry will significantly remedy this. Lastly, the use of a properly selected polarizer will block all the

road-reflected portion of the opposing light and hence improve night performance of the system as a whole during night operations.

- Accurate recognition up to 50 mph, day and night.

- Accurate recognition of "dirty" license plates (partial or full dirt coverage).

- License plate population consisting of 30-50 different samples.

### 1. Roadside Scenario

The license plates used were Thai ones, with either black lettering on white (clear as well as dirt) background, or black lettering on ruby background. Speeds were 20 mph max, with the off-axis angle extending from 12° up to 22°. The *relative* sun azimuth angle was around 87°-91° during these tests (observe the shadows in Figure 20).



Figure 20.    Roadside Scenario Vehicle

For the "hi-speed" tests, the FAST LPR team used a more sophisticated target vehicle (Figure 20) that carried the same three license plates as above. Speeds up to 50 mph were achieved and the results were very accurate character recognition in most of

the cases. There were two cases of "no trigger," but after action analysis, it was revealed that the cause was a mis-focused lens. Note that the attached Thai license plate (Figure 20) is not a clean one.

## 2.    Gate Scenario

The setting in Figure 21 reveals the gate scenario implementation used during FEX-I. The scenario was calling for the contribution of the FAST LPR set right off the main gate of the "military installation" monitoring any vehicle entering the installation through the main gate. The whole process (LP capture, image feed to the computer, and subsequent recognition and identification as "threat") was taking place locally (rather than remotely, inside the "ops center"), due to *RF interference* in the wireless link the FAST LPR team was using (deployed, evident by the tripod and the transmitting antenna embedded inside the white box attached on top of the tripod).



Figure 21.    Gate Scenario

Being locally operated, the FAST LPR "gate segment" had to be manned throughout the scenario run (refer to Figure 22). Had the wireless connection been properly operating, there would not have been the need for an operator at the gate segment. The video would be fed wirelessly to the processing FAST LPR computer inside the ops center, rendering the system "remote operated." In any case, the wireless link was not a required milestone set by the specifications for FAST LPR. Rather, it was an attempt to further investigate ways to decentralize the possible system operational implementation.



Figure 22.    Gate Scenario Operator (Author)

### 3.    System Performance

Since FEX I was the first field attempt to assemble the system and make it work, the dataset is limited. The major objective was to check the functionality of the system and the interoperability of the different components. The accuracy of the LPR was not among the top objectives. The same is true for the optics tune up. The optics (camera, lenses, filters, and illuminator) is the front end component of the system, and as such, its performance is the most critical limiting factor for overall system performance.

The camera used in FEX I was the Asia Vision Technology IR with a built in low-power illuminator (as seen in Figure 23) and the KESTREL Toshiba visible region camera shown in Figure 24. The maximum recognition distances for the cameras were measured to be 15' and 7'4'', respectively.



Figure 23.    AVT IR Camera with built in IR Illuminator



Figure 24.    KESTREL Toshiba Camera

The license plate that was initially used was a clear black-on-white (B/W) Thai plate (Figure 25) center-mounted over the vehicle's bumper. The two Thai characters on this plate stress the clarity that the optics must deliver to the OCR engine in order to reach the required total system accuracy.

With the AVT camera, in 15 passes there were four correct license plate recognitions, which resulted in an accuracy rate of 26.67%. The speeds were varying between 9 and 30 mph, with one pass made at 80 mph. Changing cameras and shifting into the KESTREL Toshiba visible region one, the number of passes made was 18 and the correct LPRs were six. Thus, there was an improved accuracy of 33.33%.



Figure 25.    Clear Black On White Thai License Plate

The relatively small maximum recognition distance for both cameras introduced another problematic factor: skew angle. The skew angle is heavily influenced by the recognition distance, as the smaller the recognition distance, the larger the skew angle. This problem is critical in the roadside setting, where for the AVT camera the skew angle[125] should be close to 47°, certainly a value not acceptable based on the system specifications. For the KESTREL Toshiba camera, this was even worse, as the skew

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[125] Abiding by the interstate standards, 12 feet lane width and another 5 feet safety distance.

angle should be close to 53°. The only way to improve the experiment was to lose the interstate standard distance geometry and move the camera closer to the lane. That way, the FAST LPR team managed to control the skew angle between 23° and 26°.

Having said that, the system low performance, as expressed by the 26.67% and 33.33% accurate LPR, can be attributed to the induced skew angle problem, with the limited camera recognition distance being the primary causal reason. However, the lack of appropriate lenses for the KESTREL Toshiba camera and the fixed lens for the AVT camera did not leave much to do during FEX I.

## B.    FEX II

In FEX II, the decision was made to use the newly purchased L-1 IR camera seen in Figure 28 with a built-in medium-power IR illuminator. The decision for this purchase was basically the short recognition distance for both the AVT and KESTREL Toshiba cameras used in FEX I, which resulted in increased skew angles and subsequently low accuracy of the whole FAST LPR. The recognition distance for the L-1 camera was measured to be 514 inches, or 43 feet. Using the roadside geometry and abiding by the interstate lane width and safety distance, the resulting skew angle was calculated to be 14.82°, a value well below the FAST LPR maximum specified value.

Another asset the team had to use was a new capture computer with promising performance. The General Dynamics (GD) VR-2 ruggedized computer shown in Figures 26 and 27) was a promising choice based on its technical characteristics, especially compared to the older one, namely the General Dynamics XR-1 that was used in FEX I.

Figure 26.    Closed General Dynamics VR-2 Computer

Figure 27.    General Dynamics VR-2 Computer Keypad and Screen

Figure 28.    L-1 IR Camera with Built In Medium Power IR Illuminator

The results of the first day were not satisfactory. On the contrary, the system performance, as it was manifested by the correct LPR passes, was a total frustration. In a total of 31 passes, there were 16 cases where the system did not trigger at all, something that did not appear in FEX I. With no trigger, of course, there is no initiation of the OCR and thus no recognition. The no trigger failure rate was 51.62%.

From the rest of the passes where a trigger did occur, none of them were correct. That said, the system accuracy was zero. Clearly, there was something wrong with one or more of the system elements or an interoperability issue that was not present in FEX I. During the day's debriefing, the FAST LPR team decided to shift back to the older computer and try to investigate this huge drawback step-by-step.

The next day the configuration was exactly the same, with the exception of the capture computer, the General Dynamics XR-1 (Figure 29).



Figure 29.    General Dynamics XR-1 Computer (Right)

Using this configuration, there was in total 26 passes, among which 11 had no trigger, which yielded a no-trigger rate of 42.31%. This was better than the day before but still not acceptable.

The important progress, though, was that all the passes that did trigger the OCR were a total success with fully correct LPR. This meant an accuracy level of 57.69%. Comparing this accuracy level with those achieved in FEX I (26.67% AVT camera, 33.33% KESTREL Toshiba camera) was telling the team that an important step forward was made. However, the no-trigger phenomenon was a side-effect that had to be eliminated.

After the day's debriefing, and especially after the FEX II post-analysis, the FAST LPR team collected all the available material and sent it to the partner responsible for the recognition engine, the Asia Vision Technology group in Hong Kong. The company investigated the system performance and shortly before FEX III provided the FAST LPR team with a new version of the Super Robo Eye software.

## C.    FEX III

The system configuration for FEX III was the General Dynamics XR-1 ruggedized computer and the L-1 IR camera with a built-in IR medium power illuminator. From FEX II it became clear that the most challenging scenario for the FAST LPR system was the roadside one, for a number of reasons. First, the vehicle speed could vary from slow speeds (like the gate scenario) up to 80+ mph. Second, having the luxury of using the whole runway of McMillan Airfield as an interstate,[126] the FAST LPR team could also investigate the skew angles under which the system performs well. Last, the team could arrange the geometry in a way to investigate the impact of the sunlight to the accuracy of the system.

During FEX III the FAST LPR team made in total 111 passes, with speeds starting from 5 mph and extending up to 80 mph. The total number of no-trigger passes was 13, representing 11.71% of the passes. From the rest of the passes (98), all were correct, yielding an accuracy rate of 88.29%. Still, the accuracy rate was below the specified 95%, but the progress towards achieving the specification set goal was amazing.

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[126] The traffic in the runway was cut-off, with only the testing vehicle being present.

Another critically positive finding was that FAST LPR with the L-1 IR camera was not susceptible to direct or reflected sunlight, as can be seen in Figure 30. The IR camera was synchronized to the built-in IR medium-power illuminator and any incoming radiation (light, IR) that was not synchronized was cut off by the electronics section of the L-1 camera. Unfortunately, the fact that L-1 was a proprietary asset did not allow the FAST LPR team to dive into the details that made the L-1 camera far better than any other sensor used with FAST LPR.

The only negative finding during FEX III was the presence of multi-trigger events. That is, during one pass the system triggers more than once. Since the LPR was yielding correct results during these passes, this was not a worrisome side effect, but it had to be corrected for in FEX IV.



Figure 30.    FAST LPR Screenshot

After the completion of FEX III, all the results were analyzed and the recorded data, along with the video stream tapes, were forwarded to Asia Vision Technology Group to further investigate the need to have the software refined for FEX IV.

**D.      FEX IV & V**

The author did not participate in FEX IV and FEX V. As a result, there is no personally collected data set reflecting the further progress the system made, in terms of accuracy, during these two final field experiments. However, based on the action reports for both FEXs, the system gradually reached its minimum required performance (accuracy 95%).

In FEX IV, the cameras were set by the main base gate, shooting at both incoming and leaving traffic. FAST LPR recognized 50 vehicles' license plates, with only one Thai character misrecognized by the OCR engine. There were four license plates out of the 50 that were not recognized fully correct, due to the presence of the specific character. This led to a system accuracy of 92%. The videos of all the triggers were analyzed and further forwarded to the Asia Vision Technology group, to fine tune the OCR engine for FEX V and solve the problem with the specific Thai character.

In FEX V, there were 450 passes, among which 435 correct recognitions and 15 not fully correct. Hence, the accuracy reached 96.6%. For the first time in system's evaluation, in FEX V the FAST LPR team exceeded the preset goal of 95% accurate LPR.

In addition, this performance was extended to outgoing vehicles, as opposed to the specifications asking the system to be designed against incoming vehicles only. Also, the FAST LPR was tested against license plates on vehicles smaller than cars (moped Thai license plates, Figure 31) and its performance was verified in that area too, even with license plates that were not clear.

Figure 31.    FAST LPR Screenshot on a Thai Moped License Plate

The FAST LPR kiosk and demonstration point during FEX IV is shown in Figure 32.

Figure 32.    (Left to Right) Rich Guarino (A3IT), Ivan Cardenas (KESTREL) and Tobby To (AVT) in front of FAST LPR Kiosk

The number of target license plates that were used in FEX IV and V was increased in order to reach the set goal of 50 different plates. The number of samples was in excess of 500. This allowed to have a better confidence interval, as opposed to the initially planned 250 samples. Also, the variety of these plates was paired to the variety of the available types of Thai license plates.

To maximize the number of passes, the system was installed at the main gate of the Thai Air Force Wing 5 installation in the Ao Manao area. Doing that allowed the system to trigger for the whole duration there was incoming traffic, and thus increased the size of the pass sample. In addition to that, the license plates that were being shot were real-life Thai license plates; they were not perfect ones, as some of them were dirty and some of them were bent and so on. This put the FAST LPR well into a real-life testing process, with the results being better than what the specifications were calling for.

# VIII. CONOPS

## A. DEFINITIONS

Based on the International Council on Systems Engineering (INCOSE) definition of the concept of operations, "The CONOPS is a model of function and behavior." [127] In a sense, CONOPS creation can be seen[128] as a set of five concentric circles as shown in Figure 33 below.
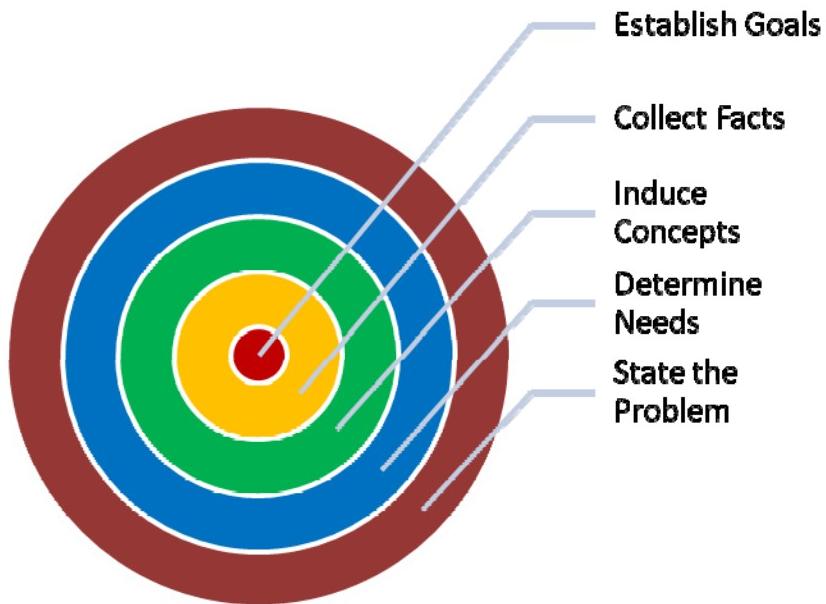
Figure 33.    CONOPS

As far as FAST LPR CONOPS is concerned, these five layers of elements have been addressed by the funding organization CNTPO and linked through NPS COASTS. As a result, a set of goals the system must be able to meet were already in place before the FAST LPR team started to visualize the whole system. The very goals of FAST LPR were visited hereby in the system's general description.

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[127] INCOSE, Washington Metro Area Chapter,
http://www.incose.org/wma/library/docs/Feb02CentrevillePresentation.ppt (accessed September 1, 2008).

[128] Ibid.

**B.      FAST LPR CONOPS**

FAST LPR will be installed initially as a pilot project in Thailand. Four systems will make up the initial array of systems installed, and after their initial use feedback will be used to further drive any changes necessary to either the system itself or its concept of daily operations. Both these elements are clearly end-user oriented, and this includes not only the–obvious–human side, but other factors as well. That is, environmental conditions, political limitations, and legal barriers are just some of potential localities that might highlight some minor adjustments to the proposed CONOPS. Despite the localized-driven needs, the majority of CONOPS has to do with the intended use of FAST LPR as though the system was to be used in the U.S. That is exactly the way the FAST LPR team approached the CONOPS creation phase (phase 3), keeping in mind that there would be some adjustments required after the system's initial operational field use.

**1.      Review Process**

Like any CONOPS document, FAST LPR CONOPS is a live document, meaning that a revision chart is needed. The process of reviewing CONOPS is a continuous one, starting at the end-user level and going up to the system development team. However, the COASTS FAST LPR team is responsible for delivering the initial system CONOPS, and as such there is no need to include herein a revision chart. Nevertheless, the primary information exchange partners are:

- U.S. DoD/CNTPO
- NPS COASTS
- Kestrel Technology Group LLC
- Asia Vision Technology, LTD
- A3 IT Solutions
- Mercury Data Systems

**2.      Reference Documents**

The reference documents usually include a broader set than simply technical manuals, guides and other documents. For instance, legislation or other legal documents

that might affect or limit the operational use of the system must be part of the reference document list. Also, this list has to be updated for obvious reasons. Being system scope-oriented, the document list for FAST LPR CONOPS is as follows:

- SUPER ROBO-EYE Installation Guide (Version 3.2) Asia Vision Technology Ltd.

- SUPER ROBO-EYE User's Manual (Version 3.1) Asia Vision Technology Ltd.

- AUTOMATIC LICENSE PLATE RECOGNITION Video Capture Guide (Version 1.0) Asia Vision Technology Ltd.

- FAST LPR Requirements and Specifications (Version 1.5.0), NPS-Kestrel Technology Group, LLC.

## 3. Current System Situation

The FAST LPR system is operational with no waivers pending to be fixed. The system has been tested and evaluated in the fixed mode, gate, toll post or by-road configuration. The proposed concept of moving mode has not yet been tested, though the Asia Vision Technology documentation allows developing an additional mode of operation, which will be further explained later on this chapter. The following paragraphs cover a more analytical perspective.

### a. What is the System?

The system is a low-cost, easy-to-use POC that performs LPR and reaches an accuracy rate of 95%. The targeted license plate character set is Thai, which poses a unique challenge due to its complexity. That is what makes the specific system, supported by OCR engines, tailored to the Thai character set "one of a kind" system that is operational.

### b. What is the System Supposed to Do?

As already explained, license plate recognition is the first step of a sequence of actions. Triggered by the recognition of a vehicle equipped with a license plate being an entry in the black list database, appropriate actions or alerts are issued by

the system to the operators, either locally or remotely (next version of the system). Then, the law enforcement authorities proceed with their actions, such as apprehension, monitoring, or further identification.

### c.      System Owner and Operator

The U.S. DoD/CNTPO is the owner and operator of the system. Also, any request for maintenance is to be discussed with the system's partners, coordinated through COASTS.

### d.      System Performance

The system performance has reached the required accuracy. In addition, system performance is stable and there are no open or unresolved issues.

### e.      Is the System Used?

The system is not yet being used by the initial end-user.

### f.      Other Systems that FAST LPR is Interconnected To

At this stage, FAST LPR is going to be used as a standalone solution, meaning that there will not be any system interconnection. However, as provisions are already parts of the design, wireless access to remote databases will be introduced in FAST LPR 2.

### g.      FAST LPR Background, Objectives and Scope

The background, objectives and scope of FAST LPR were explained earlier in the thesis.

### h.      Operational Constraints

The FAST LPR system is technically able to operate 24/7 under all weather conditions. The use of an IR camera with a built-in IR illuminator makes the system independent of ambient light. In case of adverse weather conditions like rain, snow, extreme temperatures, and humidity, there is a provision to operate it in a weatherized container. No matter how well weatherized the container might be, since the

main sensors are cameras, some performance degradation is anticipated as a result of the reduced atmospheric transmission characteristics in the visible and IR regions of the spectrum.

Another area to consider about constraining the system operation is the need for electrical power. The system components are to be powered by 100-240 Volts AC , single phase electrical power. This range makes the system almost universal with no extra devices to compensate for various electrical power characteristics around the globe. However, since mobility is a vital requirement of FAST LPR, there may be remote places where it would be hard to have electrical power at a user's disposal. For that reason, all the tests were designed using either car or marine batteries connected to a DC-AC inverter, delivering 110 VAC to all system components. Using this configuration, the only limiting factor is the capacity of the batteries used. Still, the system is fully operational with no performance degradation. As long as the system receives proper electrical power, the performance is exceptional.

Another constraint is the need to provide physical protection to the pieces of equipment that comprise FAST LPR. Especially in set-ups where multiple cameras are located in public view, away from the capture computer and hence isolated from the personnel operating the system, there may be provisions for instances of people trying to destroy these sensors. The solution to this could be a combination of making the sensor elements as less obvious as possible, as less reachable as possible, and rigid enough to increase their ability to withstand malicious actions.

### i.      FAST LPR Description

The system was described earlier.

### j.      User Profiles

User interaction is through the FAST LPR GUI. The purpose of the GUI is to keep the system details, functions, and processes transparent in order for the user to be solely focused on the system's outcome: alerts, actions, and warnings. Only one class of operational user is being designed so far, that of the system operator. However, system

maintenance is obvious another class responsible for keeping the system going, upgrading it as required, and doing the housekeeping tasks, especially regarding the locally stored databases.

### k. Support Environment

The agency responsible for maintaining FAST LPR will be a CNTPO decision. Depending on the level of maintenance needed, this might be either one or more partners,[129] or a department responsible for the operational support of the system. This in turn will mandate the proper facilities, equipment, software tools, and personnel.

### 4. Justification / Nature of the Changes

FAST LPR has no precedent system from which to inherit topology, architecture, component modules, or anything else. In that sense, it is a new technological path seen through the lens of an operational field application. As such, user suggestions to improve the product are more than welcome. However, these modifications need to be thoughtful and always looking towards the system's specific goals and objectives. In any case, justification will be required to support the customer's claims for changes. These changes might include.[130]

- Capability changes
  - Functions
  - Features
- System processing changes
- Interface changes
  - GUI environment
  - Database manipulation
- User competence changes
- Environmental changes

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[129] Kestrel Technology Group, Asia Vision Technology, A3 IT Solutions, Mercury Data Systems.

[130] Deliverable 1-10 Florida's Statewide Systems Engineering Management Plan, Appendix R: Concept of Operations Template version 2, March 7, 2005.

- Operational changes

- Support changes

These are the basic change categories, but there may be other required changes that do not fit in any of the aforementioned ones.

### a.    *Change Priorities*

Like any other technical project, all the required changes may not be feasible to implement in a timely manner. Therefore, the only way out is to find an orthological way to prioritize the proposed modifications in a meaningful way. For example, extending the range by using a new lens might be great, but it is not as critical as an important change in the system's GUI if the users find the GUI not friendly enough. Again, the prioritization of the proposed changes must be based on the operational merit of the product.

### b.    *Assumptions*

Since almost every part of the FAST LPR development has been based on a set of assumptions, if there is a projected alteration in these assumptions[131] then beyond any doubt this must be a good reason to suggest system changes. Also, if the environment is going to change, this also may be a reason for asking for system to change somewhat.

At the same time, if the legal framework changes, then again the need for some changes may be critical. For example, allowing the system to capture, along with the license plate, the faces of the passengers is not a legal barrier in Thailand. In addition, this is to be the base for the next generation FAST LPR with biometrics included as a way to exploit facial recognition mechanisms and techniques. If the legal framework in the future changes, then it is clear that the whole system has to adjust to the new data.

### 5.    Modes of Operation

The main modes of operation for FAST LPR are the following:

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[131] For example, the proficiency level of the system user is expected to change due to personnel management, or because the end-user operations are to be subcontracted to another organization.

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### a.    *Real-time LPR*

In this mode, which is the system's main mode of operation, FAST LPR is fully operational. All the system's components are operating properly. The user expects from the system–through the GUI–to get all the required alerts and actions on the fly. As the vehicle crosses the sensor's Field Of View (FOV), the system is triggered and the process starts. The license plate is captured–as image–from the camera, and it is forwarded to the OCR engine. Then, the output of the OCR engine is compared with the records from the database. Eventually, the result of this comparison triggers the appropriate alerts and proposes the suggested action to the user sitting in front of the computer's screen. It is a real-time decision loop.

### b.    *Post-capture LPR*

In this mode of operation, it is assumed that there is a disrupted flow of data from the sensing elements (cameras) to the capturing computer, or a malfunction with the capturing software or parts thereof.[132] Then, it is possible to circumvent this situation by troubleshooting the problem while setting the cameras in recording mode. Cameras may be set to continue to record the vehicles crossing their FOV and storing this NTSC video stream to tapes or digital discs. Then, these stored video streams become the input data to the FAST LPR recognition engines, yielding, if applicable, the alerts and actions that are appropriate. While not being able to issue real-time alerts and actions, FAST LPR in this configuration still can be used for post-capture LPR. This is a back-up or emergency mode. This mode can be also viewed as an inexpensive way to gather data (video streams) for post LPR, for a number of reasons such as the following:

- Personnel training
    - Easier and cheaper to train the users in a controlled environment such as a classroom, using video streams, compared to the field training
    - Cost effective solution for the initial user familiarization with the system and the GUI

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[132] Digitizing process, computer underperformance, GUI temporarily not performing as expected, need to reboot the computer, and so on.

- Capturing the sensor's suitability for FAST LPR

    - Using the video stream captured from candidate new sensors is the best way to figure the suitability of these sensors for FAST LPR

    - No need to allocate funds, personnel, and time by going to the actual field in order to evaluate the sensor; only the senor needs to be taken to the capturing area to record the passing vehicles

- Capturing sensors' comparison

    - Using video streams from different sensors, keeping all other parameters the same, this is the best way to do a comparative new sensors evaluation in the lab

- Evaluating/extending the capabilities of sensors already in use, by attaching numerous lenses, changing iris settings, or altering other camera's parameters. In short, only the sensor under modification needs to be physically present at the capturing point, be it a toll post, roadside, or other location. The rest of the equipment stays in the lab.

## 6. Operational Scenarios

### a. *Gate / Toll Post Fixed Scenario*

This scenario assumes that the FAST LPR system is used to monitor the traffic activity entering/exiting an installation or passing through a toll post-like kiosk. The nature of that traffic is that vehicles are supposed to decelerate a little, as opposed to the case of free-flow traffic on an interstate or other road. Even if there is no need for the vehicles to come to a complete stop in order to have some interaction with the kiosk personnel (if any), then the fact that cars have to pass through relatively narrow lanes is enough to result in them reducing their speed. This fact, along with the ability of FAST LPR to accurately capture license plate images on cars being driven with speeds of up to 70 mph, makes the system fully compatible with the specifics of traffic passing through these posts.

Another important factor in this scenario is that the cameras can be fully horizontally aligned with the trajectory of the vehicle. The only off-axis angle is the vertical angle, as a result of the height above the road the camera is mounted at. This introduces the potential problem of excessive skew angle. However, for a typical camera height of 12 ft. and a nominal recognition range of 60 ft., then the skew angle becomes

11.5°. This angle is way less than the FAST LPR maximum[133] skew angle of 20°. The recognition distance of 60 ft. is dependent on the optics of the camera, and mainly the lens used. With readily available[134] camera lenses recognition distances can easily go up to 100 ft. or even more. However, the nominal distance of 60 ft. is used as the basic reference herein. Also, the camera height of 12 ft. is an average height used for calculations. With the recognition distance of 60 ft., in order to reach the nominal maximum skew angle of 20° the camera must be positioned at a height of 20.5 ft., which is pretty high for any toll post kiosk. If one takes into consideration the fact that even with skew angles of 25° the system continues to perform accurately, then as far as the optics is concerned, in this operational scenario the geometry of the setup does not face any limitations.

This scenario is feasible with both FAST LPR modes of operation: real-time and post-capture LPR. The only difference is the delay in the implementation of the proper actions after the system issues its alerts. In real-time LPR, the vehicle, if its license plate is a match based on either the threat list or the suspect list of the database, can be stopped for further identification or other action by the appropriate personnel within seconds. In post-capture LPR, this may not be possible. However, especially if the vehicle was on its way into an installation or controlled area, it is a matter of time to take the proper action at a later time. A typical gate-entry configuration is shown in Figure 34.

The gate and toll post scenario is also applicable on interstates, with the cameras–one for each lane–mounted on horizontal poles like those used for traffic signs. In this configuration, given the increased height of the supporting poles, hence the increased camera height (Figure 35), the need for increased recognition distances using appropriate lenses is obvious.

With a nominal height of 18-20 ft., there is no concern about the resulting skew angle. Even with a short recognition distance of 60 ft., the skew angle will be close to 19.5°, less than the FAST LPR specified one.

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[133] Per FAST LPR specifications.

[134] And inexpensive.

For the gate scenario, as well as the cases where FAST LPR will be fixed to monitor a specific junction or a curved turn, the proposed installation is shown in Figures 36 and 37.



Figure 34.    Typical FAST LPR Gate Configuration
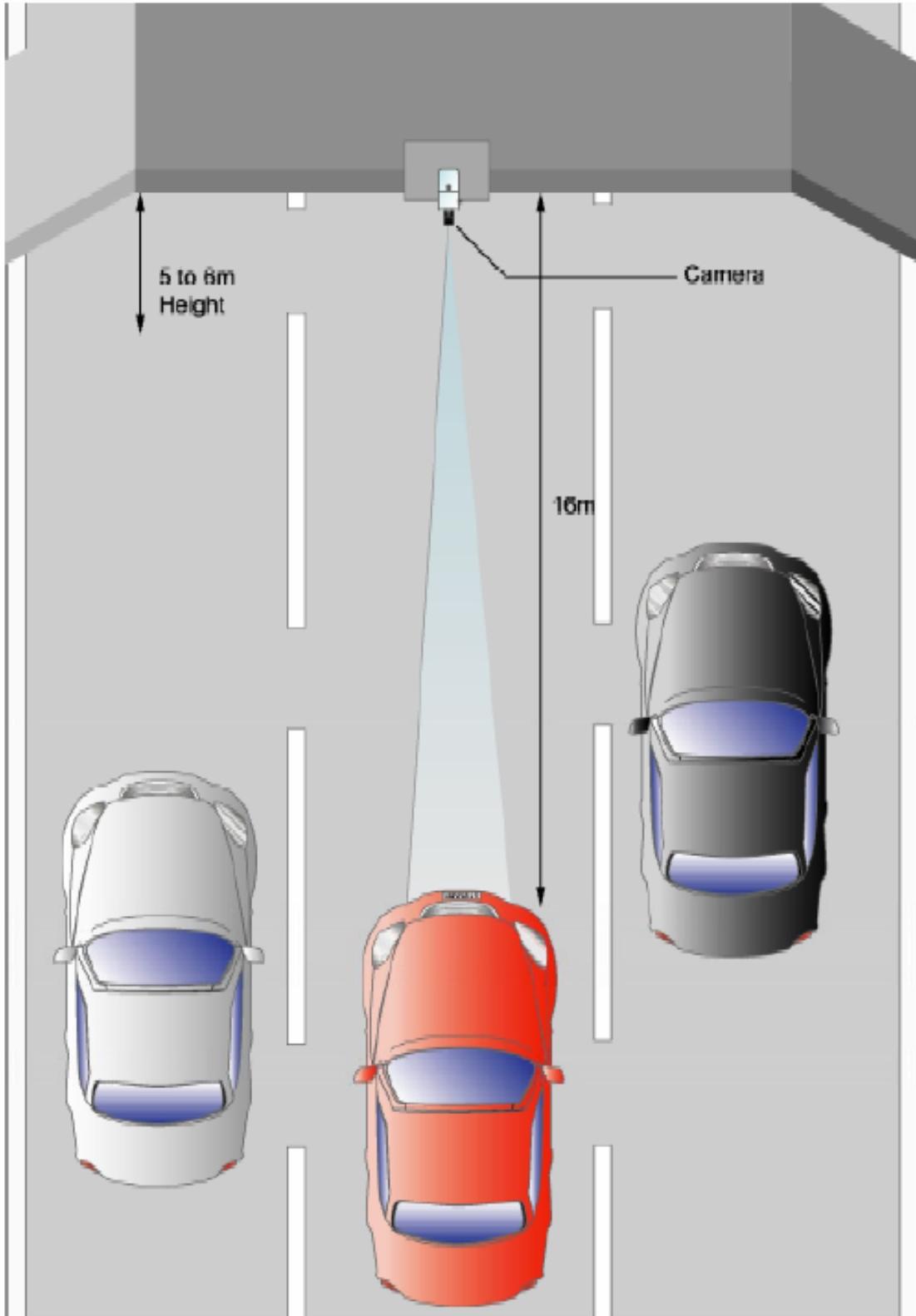
Figure 35.    Toll Post/Interstate Lane Configuration
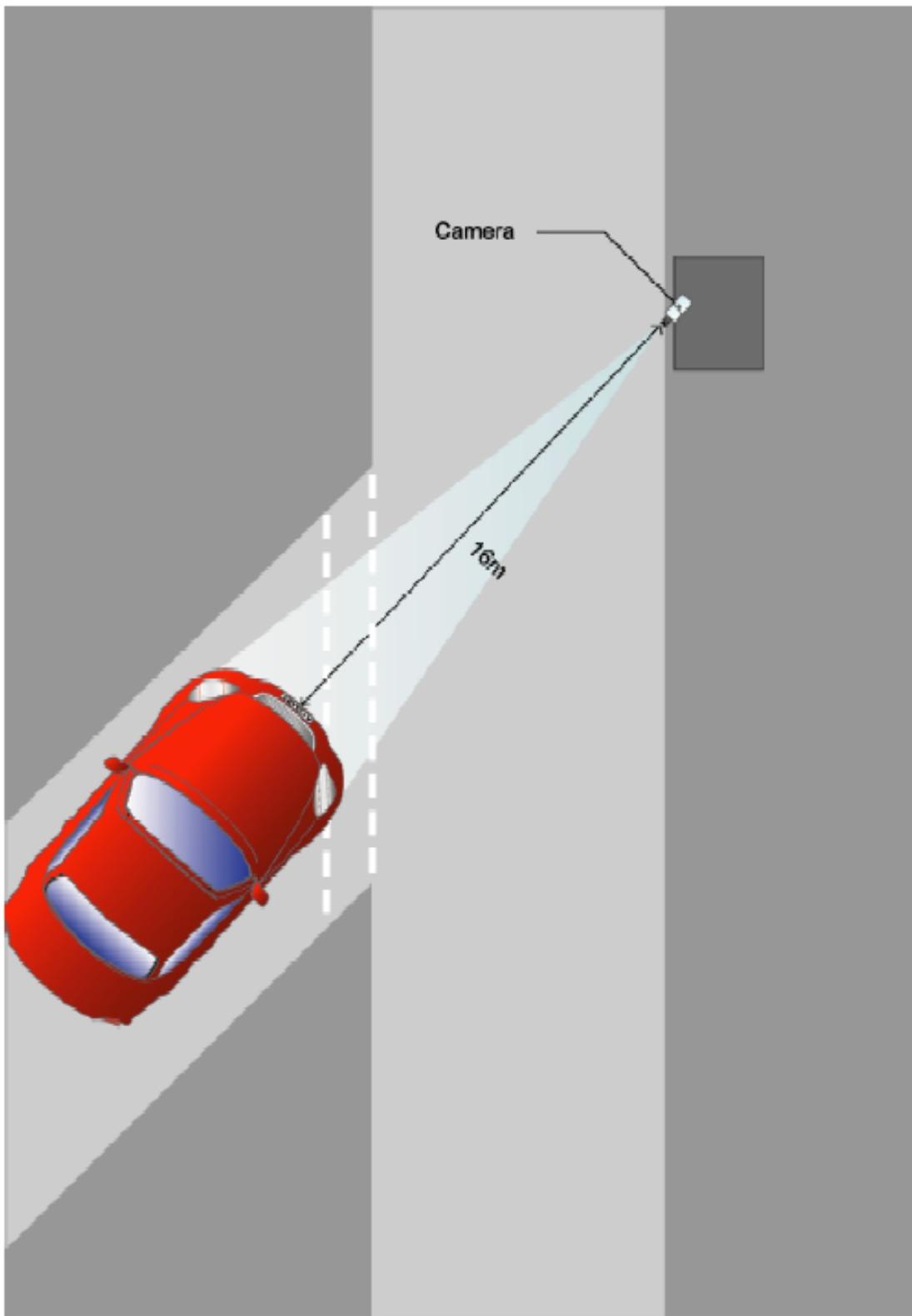
Figure 36.    Junction FAST LPR Configuration
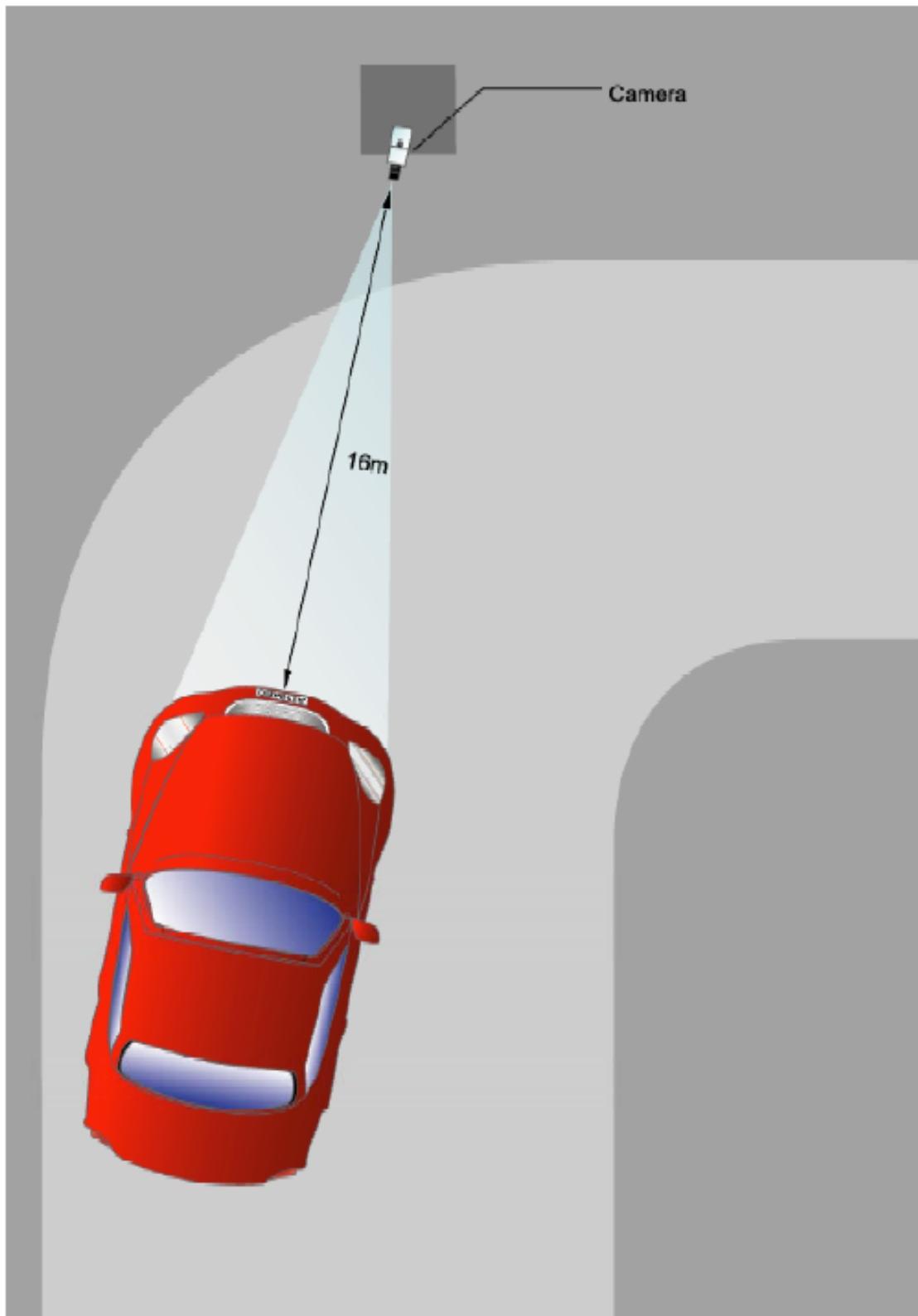
Figure 37.    Curved Turn FAST LPR Configuration

### b. *Roadside Fixed Scenario*

There are many common things between this and the previous scenario. In both cases, the camera is fixed, most likely on a horizontal bar (toll post scenario) or a tripod (both gate and roadside scenario). The system is dedicated to one lane only (toll post / gate scenario) or mainly one lane mainly for the roadside scenario. In both cases, there is a certain skew angle. In the gate and toll post scenario, this skew angle is primarily due to camera height. In the roadside scenario, the skew angle is primarily a horizontal one, with the vertical element of it almost negligible.

In this scenario, the skew angle is caused by the horizontal displacement of the camera being on top of a tripod (high mobility feature) and the operator has to mount the tripod/camera off-road. Such a set up is shown in Figure 38.



Figure 38.    FAST LPR Team Prepares the System for the Roadside Scenario

With a nominal lane width of 12 ft.[135] and the tripod/camera located in the middle of the shoulder (5 ft.), the resulting skew angle for the leftmost lane becomes 10.5° and for the second leftmost lane 22.5°. In this scenario, it is also assumed that the vehicle is moving along the center of the lane. Based on the FAST LPR accurate performance of skew angles in the order of 25°, the system can effectively monitor two lanes. With a better lens, which yields a recognition distance of 100 ft., the numbers are as follows:

| | |
|---|---|
| Leftmost lane skew angle: | 6.32° |
| Second leftmost lane skew angle: | 13.29° |
| Third leftmost lane skew angle: | 20.49° |

Clearly, a small increase in the recognition distance allows the system to monitor three lanes at the same time. Of course, if two vehicles are within the cameras line of sight simultaneously, only the license plate that is not occluded will trigger the FAST LPR system and the recognition will be done for that license plate. The Asia Vision Technology Group proposal for the implementation of this scenario is shown in Figure 39.

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[135] The minimum U.S. interstate lane width.
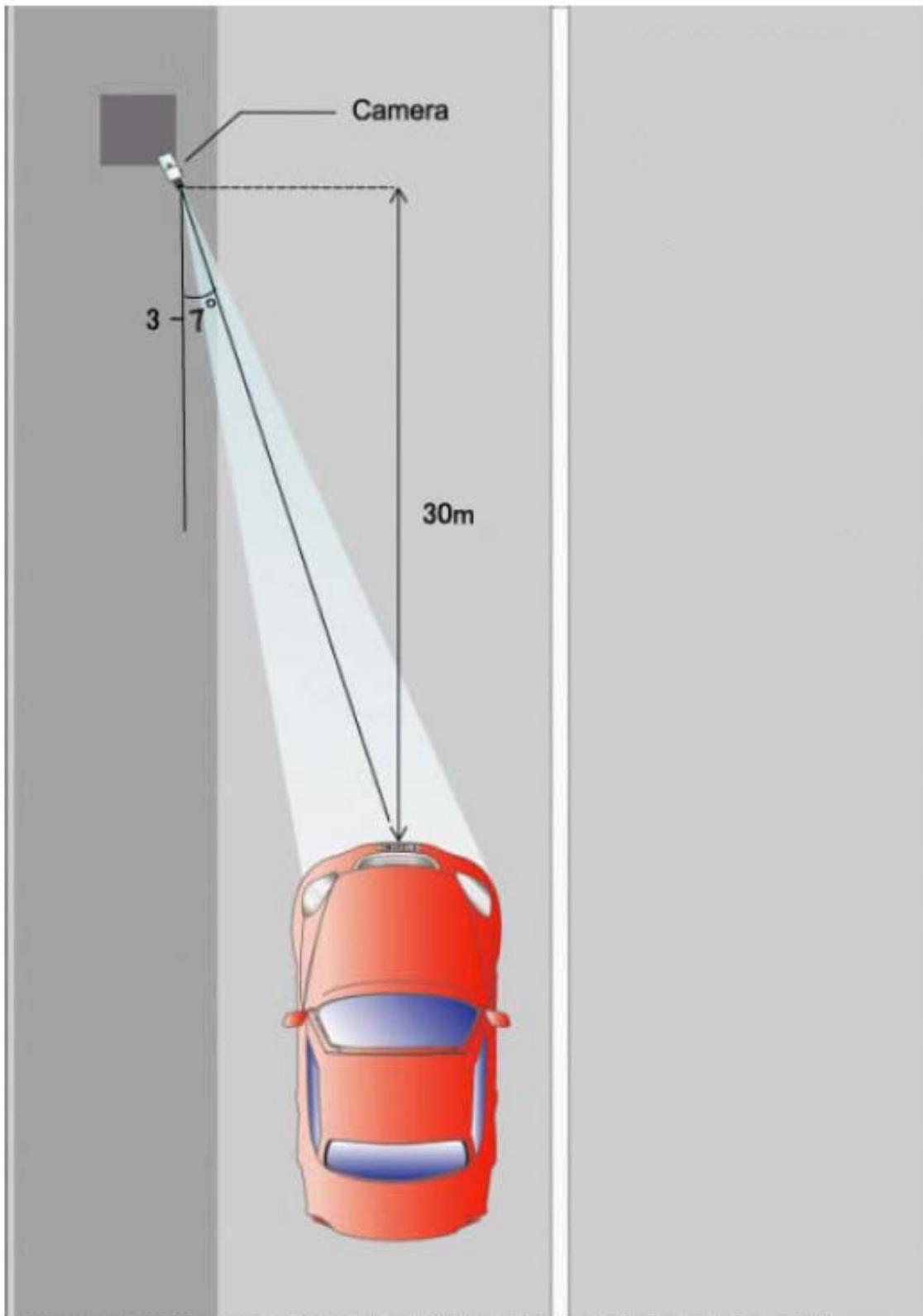
Figure 39.    Roadside FAST LPR Configuration

### c. Car-mounted Camera Scenario

This is different from both of the two previously described scenarios. The difference is that here the camera is mounted on a car being driven as part of the overall traffic. Such camera mounting options are shown in Figure 40. This scenario assumes that the whole FAST LPR system is installed inside the car. The cameras are installed on the roof of the car, or could be also installed on a specially designed door-windows mount. With predefined recognition distance, there is a variety of combinations of skew angle versus lane-to-lane distance for effective license plate recognition.



Figure 40.    Car-mounted Cameras

The primary mode is for the law enforcement vehicle to be moving in a lane targeting suspicious vehicles moving in the adjacent lane (right or left, Figure 41). Since the system will trigger both when approaching and leaving the target vehicle, there is relative flexibility on the movement of the law enforcement car. A detailed figure about this scenario is shown in Figure 42. This scenario lends to the FAST LPR system

even greater mobility and the ability to be when it is really needed on short notices. However, it is more expensive to install all the required pieces of equipment on specific cars, and there is the downside of compromising the covert operation of FAST LPR, compared to the roadside scenario. It is a useful implementation for addressing illicit trafficking using vehicles in the urban areas, allowing for greater coverage with unpredictable points of presence, as opposed to the fixed locations.

As far as the in-car installation of all the required components, the Asia Vision Technology Group proposes two alternative ways:

- The whole system receives power from the car's 12/24V sockets, using the car's battery (Figure 44)
- FAST LPR is powered from a dedicated system battery (Figure 45)

A demonstration of the second implementation, with a dedicated FAST LPR battery installed in the trunk of a law enforcement car is shown in Figure 43.
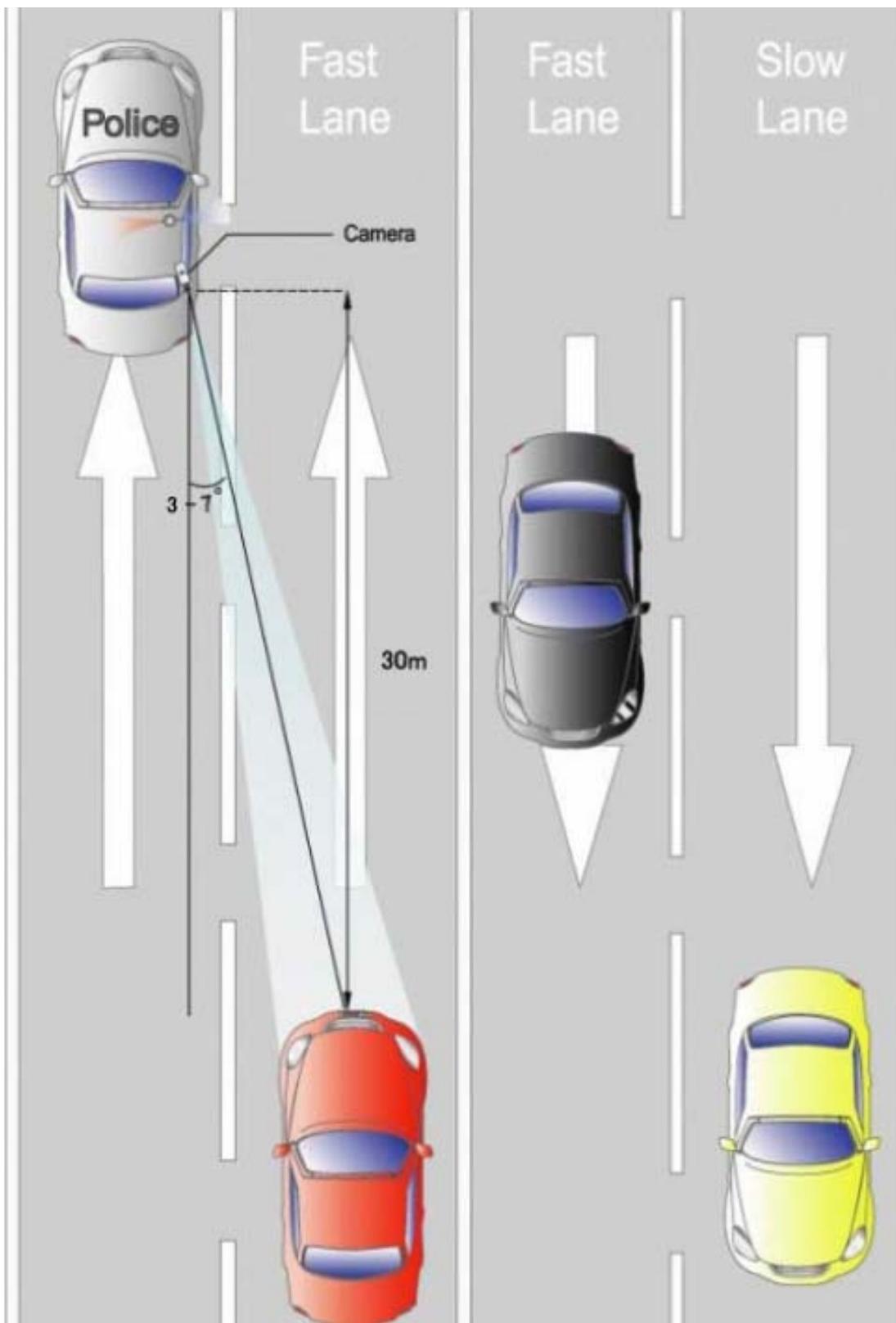
Figure 41.    Car-mounted FAST LPR Configuration
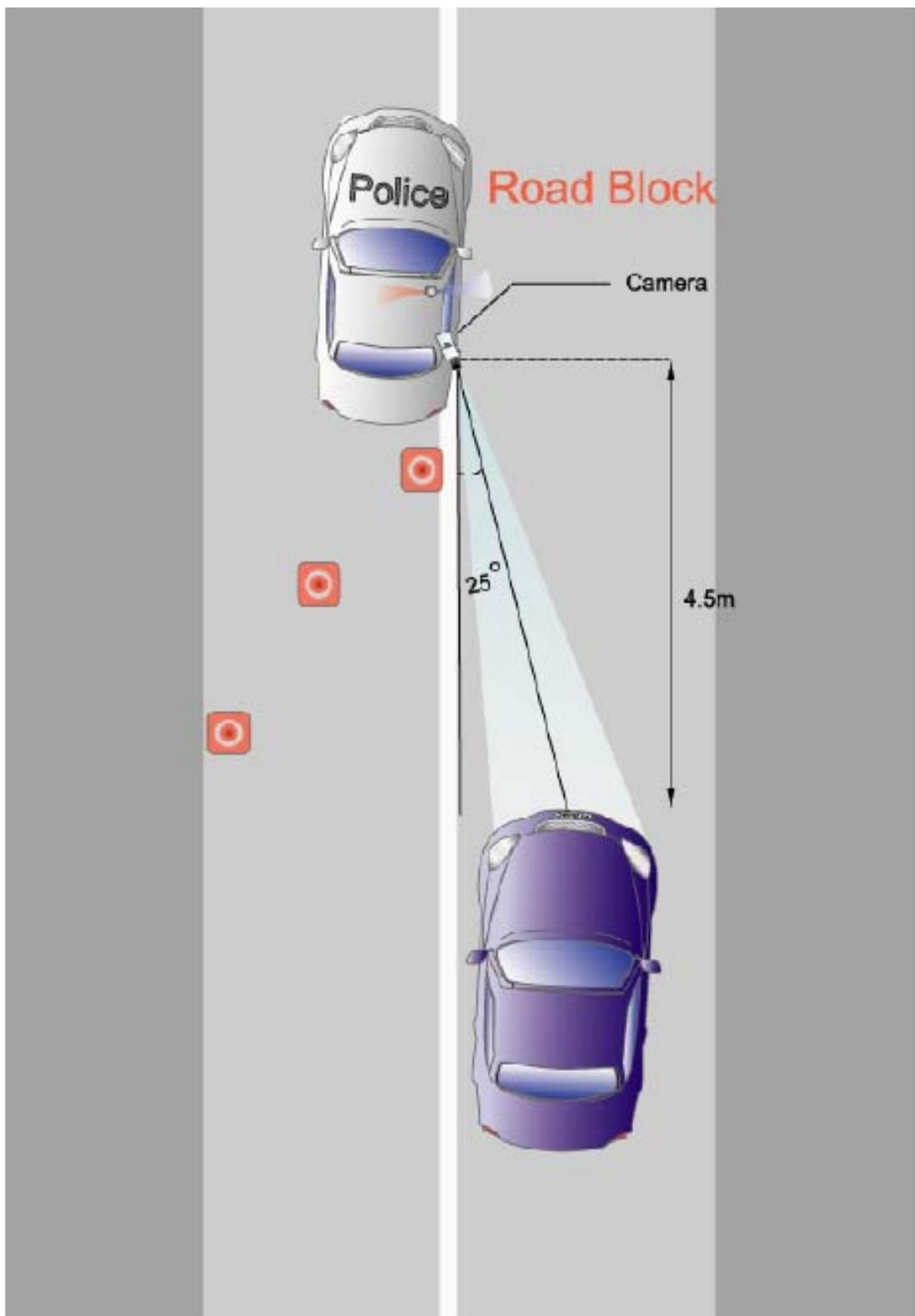
Figure 42.    Car-mounted FAST LPR Road Block
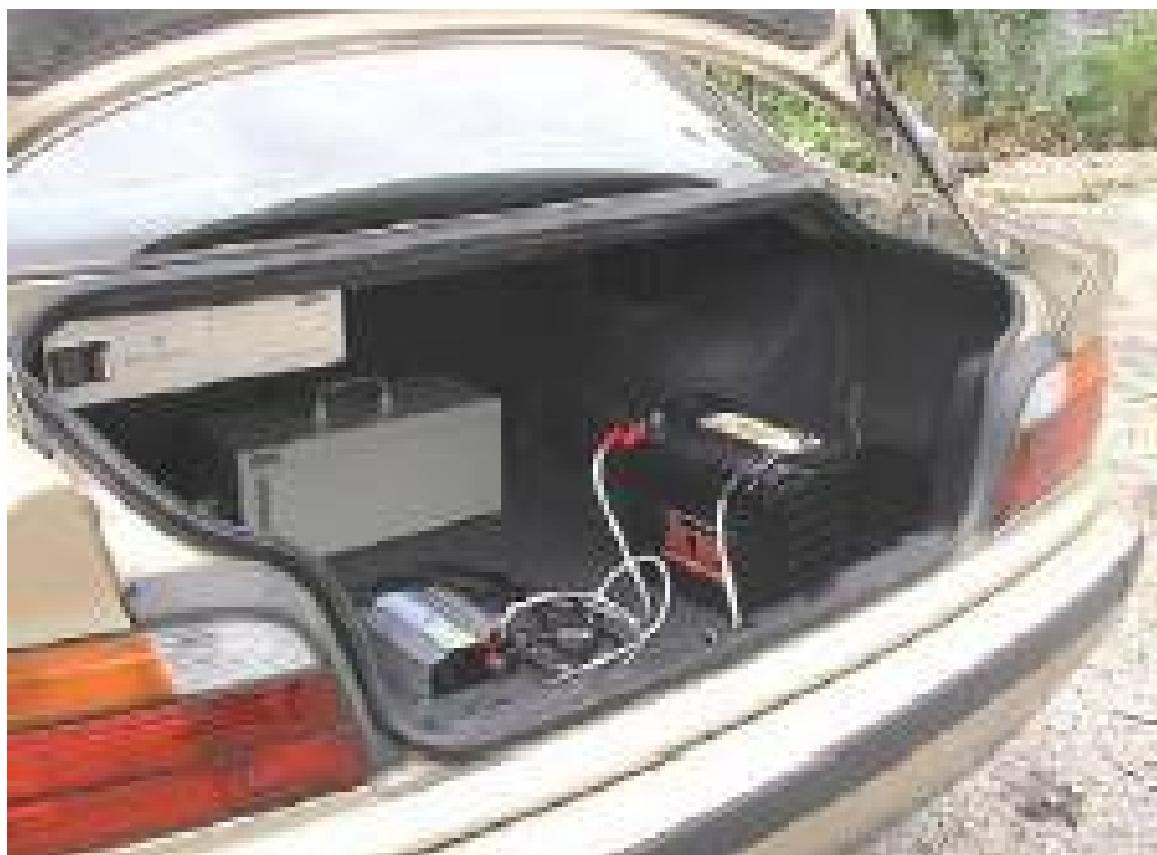
Figure 43.     FAST LPR Dedicated Battery Installation
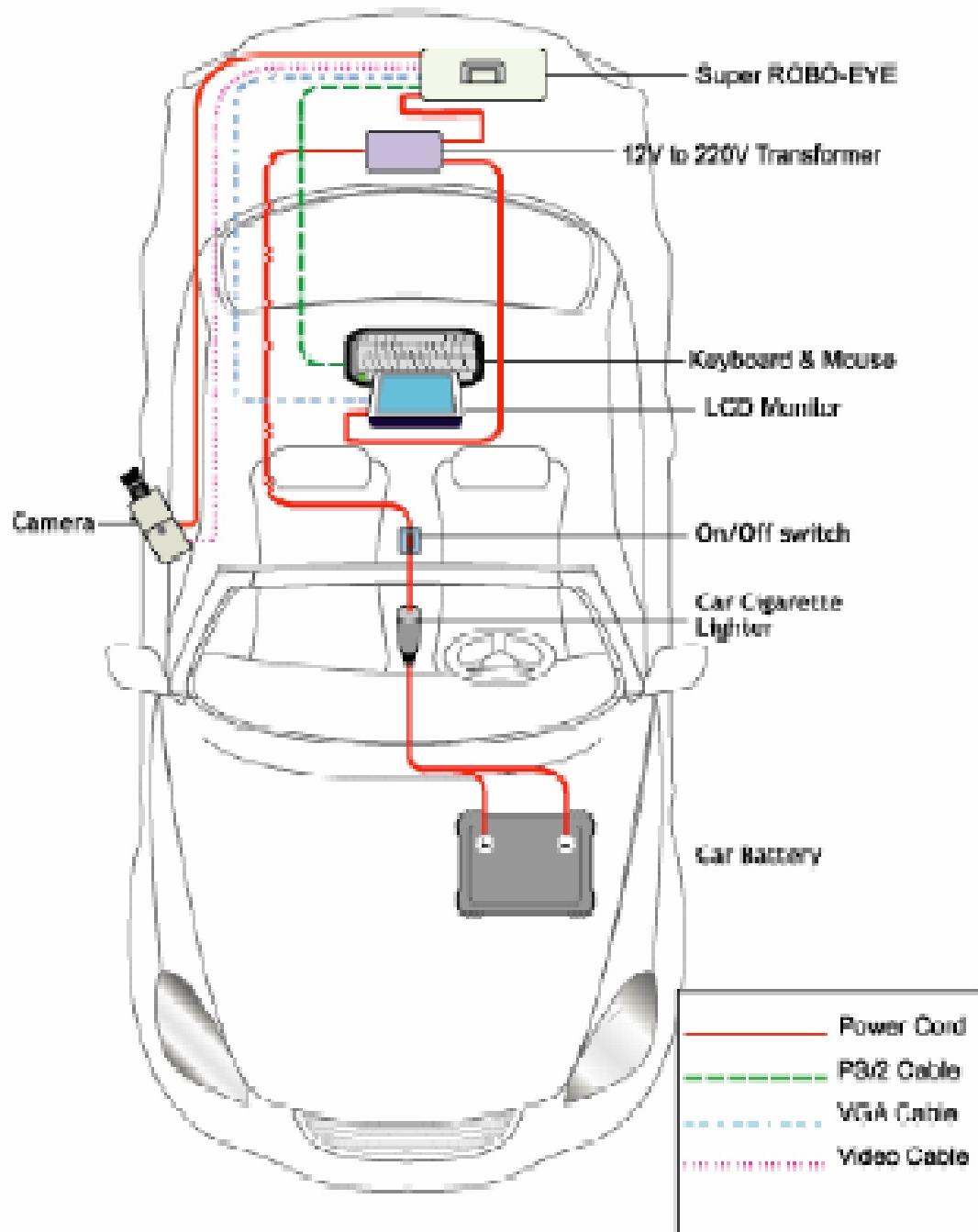
Figure 44.    FAST LPR Car Battery- Powered Configuration
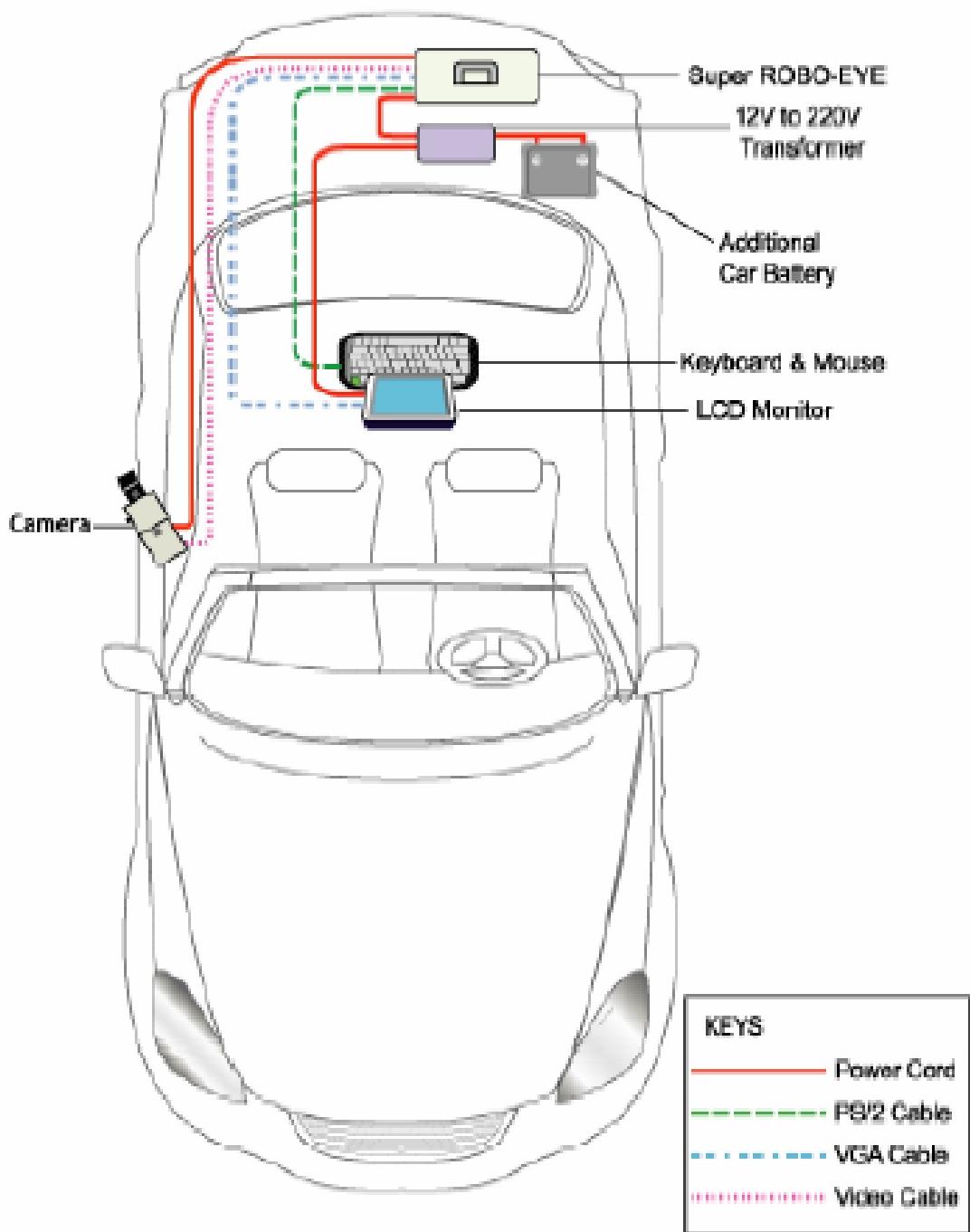
Figure 45.    FAST LPR Dedicated Battery-Powered Configuration

# IX. CONCLUSION

National security is critical for any country and its very existence. At the moment, that a country becomes unable to secure itself, the countdown begins. Such countries, being unable to defend their sovereignty, become the perfect geographical spots for the drug lords to establish their illegal businesses. These businesses are usually located in remote areas, near the borders and preferably in hard to reach terrain. That way, illicit drug production enjoys tranquility as far as the government's intervention is concerned. The impact on national security is crucial. Narcoterrorism has become a very serious problem, not only at the national level, but also at the international level too.

Drug production is just one link in the drug chain from production to final delivery throughout the globe. After the product, either in its final form or an intermediate one, is ready to ship the illicit drug trafficking starts to function. This is the most risky phase. The drug lords, being profit oriented, seek ways to reduce this risk. This may mean that a shipment has to be delayed, rerouted, or heavily protected by any means. In order for them to minimize the risk, this required protection passes to terrorist groups. These groups offer their protection at a cost that might be enough for them to fund their terrorist activities yet affordable for the drug lords, in light of the risk their loads of illicit drugs face. Both drug lords and terrorist groups that support the illicit drug trafficking partake in a win-win situation. Often this relationship, clear in theory, does not seem to have a clear-cut line between the drug production and the drug-trafficking, to the extent that even the special law enforcement authorities admit that they become indistinguishable.

The industry that is built around illicit drugs is increasingly sophisticated. The nature of the illicit drug trafficking threat is very serious for another reason, as it resides in between the international and national level, rendering the appropriate counter-narcoterrorism effort much harder. Where one nation's forces stop having jurisdiction in pursuit of drug traffickers because of border crossing, the neighboring nation's forces may not be ready or willing to engage. Even if they are, it takes time to coordinate, and the delay due to this hand-off usually is enough for the traffickers to escape. This is a

favorite scenario for the traffickers, since they take advantage of the lack of cooperation of their opponents. Being very well-equipped, illicit drug traffickers use technology in their favor to avoid law enforcement, or if this is not feasible, engage with them with better situational awareness. It is not uncommon for the traffickers to be armed with far better weapons and more sophisticated equipment. The case of the Colombian drug cartel planning to purchase a Russian submarine fully-manned to use for their illicit drug trafficking might sound extreme, but it is far from being fictitious.

There are other impediments in the attempt to contain the illicit drug trafficking. For example, the nature of the force to be responsible for dealing with narcoterrorism is still debatable. This force must have the right to pursue the traffickers, even if it has to cross borders. Legal issues at a bilateral as well as international level need to be solved. This thin balance between maximizing the effectiveness of such a force and respecting the sovereignty of the neighboring nation is hard to overcome. That is why the main effort to contain the loads of illicit drugs takes place along major trafficking routes within countries or at the main entry/exit points.

In Thailand, in recent years the vast majority of illicit drug load seizures were not made along the road network of the country, despite the fact that drug traffickers use it as their method of choice to push their load to Bangkok. Either in the northern region of Thailand or the southernmost Muslin provinces, something needs to be done to better safeguard the road network from the unimpeded flow of illicit drugs, hidden in vehicles. Neither the police nor the army is a credible deterrence force. The army is primarily focused on the various low-scale external threats the country faces and its forces are operationally dispersed across the borderline. On the other hand, the police are not trained and manned to deal with counter-narcoterrorism. In fact, in certain areas, like the Muslim southernmost provinces, police operations might have a negative outcome since there is a long tension between law enforcement and the local populace, attributable to extremely harsh police measures against the Muslims.

A long-term solution for Thailand's effort to achieve the 2015 ASEAN's goal of a drug-free region might need international support and cooperation as well as a deeper analysis and commitment. However, small steps can be taken to pave the way for a more sustainable and permanent solution.

Technology is not only on the side of drug traffickers, but on government forces as well. Systems that enhance the efficiency of the existing counter-narcoterrorism forces are the first step to take while looking for a permanent solution in the future. Smart systems that do not need more than a handful of operators and are highly mobile as well as easy to operate throughout the country could especially contribute to effectively reducing the illicit drug trafficking along the dense road network in the country.

FAST LPR falls into this category of systems. It is highly mobile, does not call for more than one or two operators, and could be used either locally or remotely. Another advantage is that it may be used overtly or covertly, in fixed as well as non-fixed spots, and can be used for real-time LPR and subsequent apprehension or post-LPR. It is a 24/7 system that in its weatherized containers can operate under direct sunlight or during dark conditions. Its architecture allows for modifications in both the software and the hardware to fine tune the system's performance to the needs of the end user. Its COTS orientation allows the user to interchange structural elements with new ones as they become available. Its CONOPS, as developed by the author, fills a broad operational gap, but it is very easy for the end user to design new tactics for maximizing the system's capabilities.

The FAST LPR 2 system will implement advanced biometric data processing, further increasing the system's performance. Wireless connectivity will provide a global character to FAST LPR 2. The user will be able to operate the system from anywhere in the world through the Internet. Thus, the number of available databases containing the required data sets will be dramatically increased. Overall, FAST LPR 2 as a posterity system of FAST LPR will provide the counter-narcoterrorism forces a unique tool for doing their job with unprecedented capabilities.

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# APPENDIX A. TESTING FACILITIES

## A.     CAMP ROBERTS

Field experiments I, II, and III took place in Camp Roberts. A generic map for Camp Roberts is shown in Figure 46.
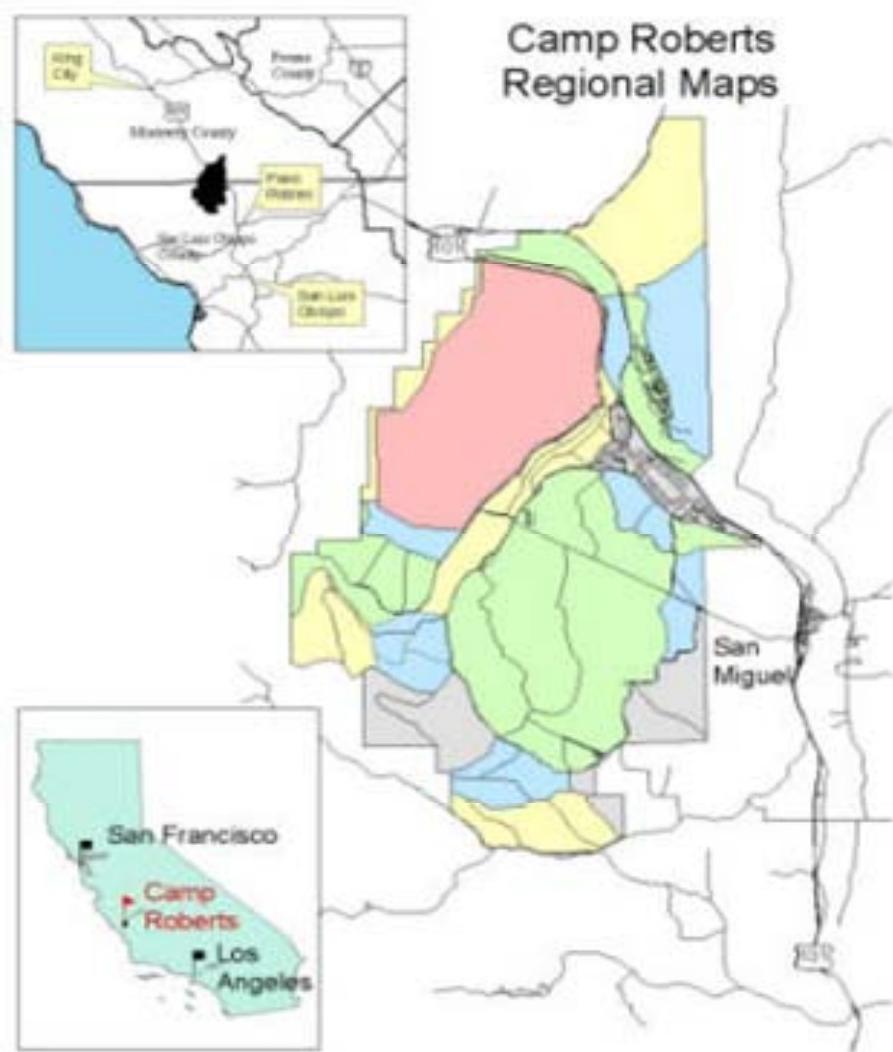


Figure 46.    Camp Roberts Map

In addition, for specific events in all three FEXs the airspace over the McMillan Airfield (inside Camp Roberts) was reserved. A detailed map of the McMillan Airfield and the affected airspace is shown in Figure 47.



Figure 47.    McMillan Airfield Airspace

A view of the airstrip in McMillan airfield is shown in Figures 48 and 49.
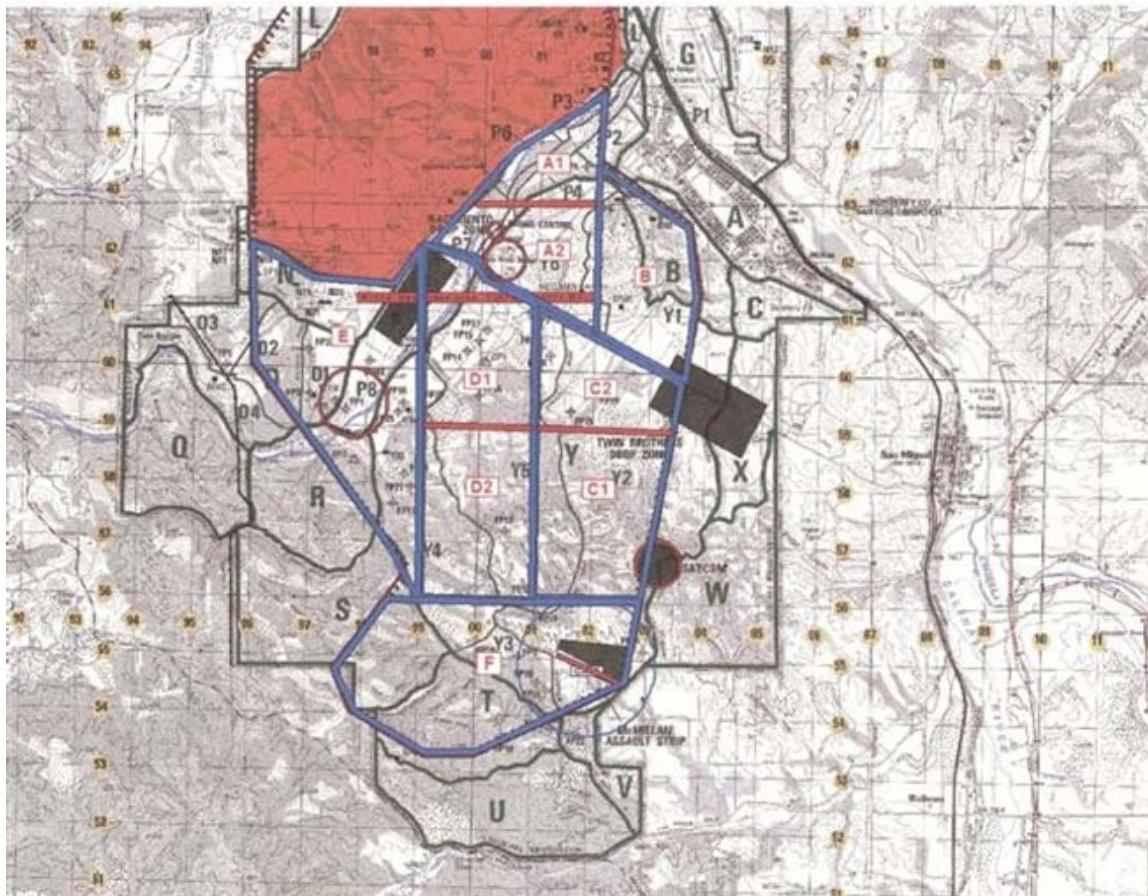
Figure 48.    Active Runway in McMillan Airfield, Camp Roberts[136]



Figure 49.    East Threshold of Runaway (FAST LPR Roadside Scenario)[137]

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136 Google, http://maps.google.com/maps?hl=en&tab=wl (accessed March 19, 2008).

137 Ibid.

## B.    WING 5, AO MANAO, THAILAND

FEX IV and V took place in Thailand. More specifically, the COASTS team was hosted in Wing 5 at Ao Manao, in central Thailand (Figure 50) in the Prachuap area (Figure 51).



Figure 50.    Wing 5, Ao Manao Airbase, Thailand

Figure 51.    Prachuap Khiri KhanArea, around Wing 5

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# APPENDIX B. THAI LICENSE PLATES

The fact that the Thai character set is very complex is not the only challenge for the OCR engines. In the case of the license plates in Thailand, the color combination (background and lettering), the various picture-like backgrounds, and the reflectivity of some of them makes the OCR engines suffer moderate performance. In Table 13 below, a set of various Thai license plates is presented.

| | |
|---|---|
|  | Company registered vehicle license plate: 2 Green letters and 1, 2, 3 or 4 green digits, on a white background. |
|  | Temporary, dealer issued license plates for car: Black letter(s) and 1, 2, 3 or 4 black digits, on a red background. Driving with this type of license plate does have some restrictions. More on the new rules coming soon |
|  | Temporary, dealer issued license plates for a truck: 5 white digits, on a red background. Driving with this type of license plate does have some restrictions. More on the new rules coming soon. |
|  | Most common passenger car license plates: 2 black letters and 1, 2, 3 or 4 black digits, on a white background. |
|  | Personnel transport license plates: 2 blue letters and 1, 2, 3 or 4 blue digits, on a white background. |

| | |
|---|---|
|  | Diplomatic car license plate. No further information available at this time. |
|  | The Royal Family's or Royal household license plate. 3 white letters in Thai script and 4 white numbers in Thai script on a black plate. |
|  | Royal Thai Navy license plate. 5 white numbers in Thai script on a black plate. |
|  | Recently several Thai provinces have started issuing license plates with a colorful design background. Currently this type of background is only available for the license plates that are bought in the Department of Land Transportation' s auctions and not for common license plates. |
|  | New!! Chiang Mai provincial license plate. |
|  | New!! Rayong provincial license plate. |
|  | Khon Kaen provincial license plate. |

Table 13.    Thai License Plates[138]

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[138] Thai Car License Plates, http://driving.information.in.th/license-plates.html (accessed April 28, 2008).

As far as the various background patterns, Table 14 shows a number of them.

| | | |
|---|---|---|
|  |  |  |
| Chiang Rai | Petchaburi | Udon Thani |
|  |  |  |
| Pathumthani | Buriram | Nahkorn Si Thammarat |
|  |  |  |
| Nakorn Prathom | Nakorn Sawan | Nonthaburi |
|  |  |  |
| Roi Et | Ubon Rachathani | Ratchaburi |
|  | | |
| Suphanburi | | |
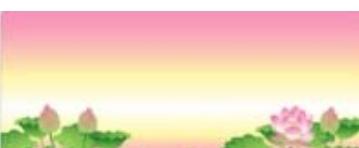
Table 14.     THAI License Plates' Various Background Patterns[139]

[139] Thai Car License Plates, http://driving.information.in.th/license-plates.html (accessed April 28, 2008).

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# APPENDIX C. MISCELLANEOUS EQUIPMENT USED IN FEXS



Figure 52.    EXTECH Light Meter



Figure 53.    Marine Battery and DC-to-AC Inverter

Figure 54.     Various Thai License Plates with Flaws



Figure 55.     Various Brand New Thai License Plates

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